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NBS-GCR-82-409

Feasibility Study for Resource Recovery: Southwest Brooklyn Incinerator

September 1982

Prepared for
Office of Recycled Materials
National Bureau of Standards
Washington, DC 20234

NBS-GCR-82-409

FEASIBILITY STUDY FOR RESOURCE RECOVERY: SOUTHWEST BROOKLYN INCINERATOR

Resource Recovery and Waste Disposal
Planning, Department of Sanitation

The City of New York
Department of Sanitation
51 Chambers Street
New York, NY 10007

September 1982

NB81NADA2043

Prepared for
Office of Recycled Materials
National Bureau of Standards
Washington, DC 20234

The City of New York Department of Sanitation

Norman Steisel Commissioner

Resource Recovery
And Waste Disposal Planning

Paul D. Casowitz Deputy Commissioner
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September 23, 1982

Ms. Terry Matthews, Manager
Technical Advisory Center
Office of Recycled Materials
National Bureau of Standards
Washington, D. C. 20234

Re: Grant No. NB81NADA2043
Energy Recovery from Existing
Municipal Incinerators

Dear Terry:

I am pleased to submit to you the final report of the Feasibility of Resource Recovery at the Southwest Brooklyn Incinerator. The study was conducted by Weston Engineers and Black & Veatch, under a contract with the City's Department of Sanitation. The Power Authority of the State of New York has been an active participant in the project and is interested in its ultimate implementation.

Based on technical and economic investigations, the report recommends the generation of electricity with the flexibility of extracting steam in the future for district heating purposes. The recovery of ferrous and aggregate from the residue also appears promising.

The City and the Power Authority are optimistic that this project can be implemented. We are greatful to the assistance provided by you and your agency in moving the project closer to fruition.

Very truly yours,

Harry Szarpanski, P.E.
Project Director

HS:ec
Enc.

Aux

City of New York
Department of Sanitation

Power Authority
of the State of New York

Feasibility Study for Resource Recovery

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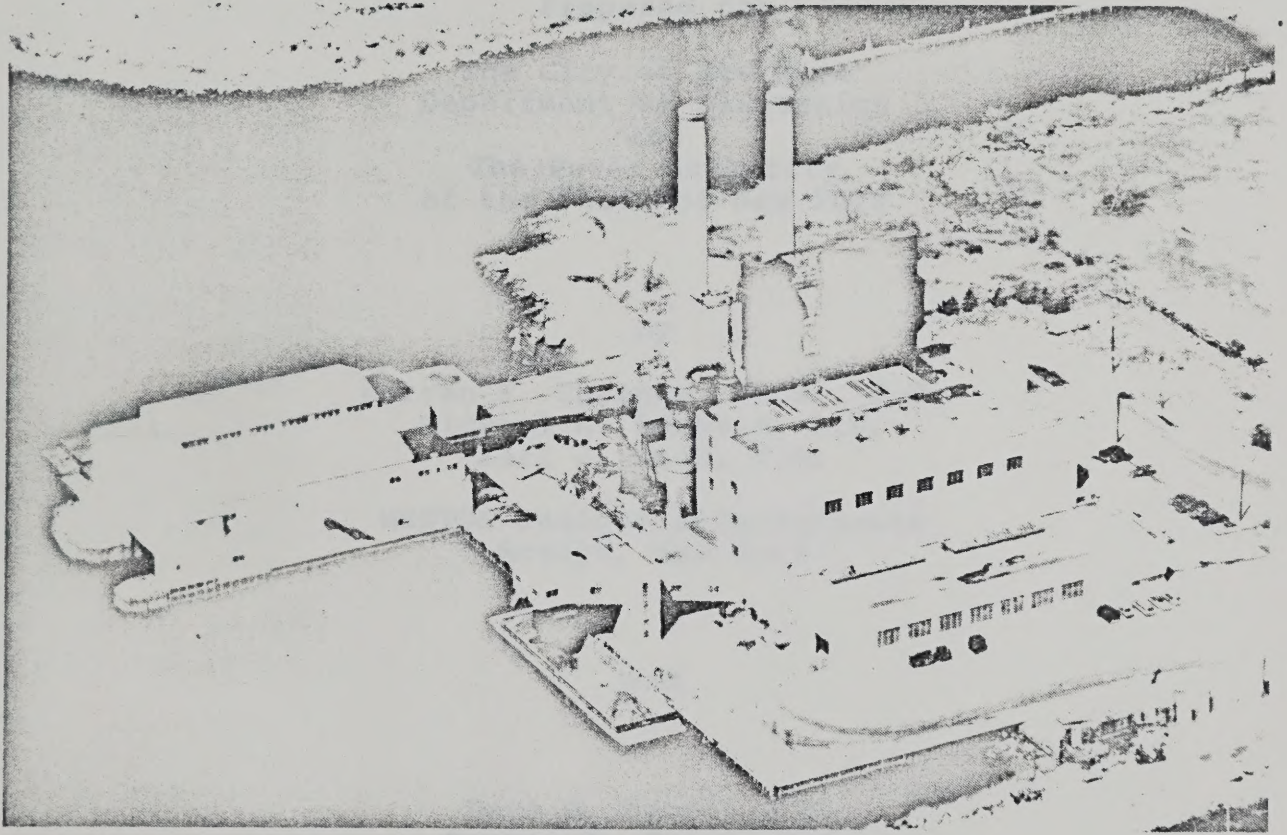
ENERGY DEPARTMENT



Southwest Brooklyn Incinerator

Prepared by

WESTON
DESIGNERS CONSULTANTS

Black & Veatch
Consulting Engineers

September 1982

FEASIBILITY STUDY FOR RESOURCE RECOVERY
SOUTHWEST BROOKLYN INCINERATOR

Prepared for

The City of New York
Department of Sanitation
and
The Power Authority
of the State of New York

by

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31 August 1982

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W.O. 2147-01-01

Subject: Feasibility Study for Resource Recovery,
Southwest Brooklyn Incinerator
Contract #1P00269

Gentlemen:

We are pleased to submit the final report covering a Feasibility Study for Resource Recovery at the Southwest Brooklyn Incinerator. The report is the product of a comprehensive investigation of the technical and economic requirements for recovering energy and residue materials at the Southwest Brooklyn Incinerator. The results indicate that a unique opportunity exists for the City of New York and the Power Authority of the State of New York to utilize an existing solid waste incinerator installation for the generation of electricity and/or steam for district heating and the potential for recovering residue ash for use as asphalt aggregate in City-owned asphalt plants.

Modifying the existing facility for electricity generation with the flexibility for future district heating capability is unusually attractive since the projected return on investment is considerably higher than for a "grass-roots" waste-to-energy project. Also, the incinerator operation is established at the site with refuse handling patterns and residue disposal methods functional and operating. As a result, the licensing and permitting requirements will be significantly reduced as compared to a new facility.

This project can be completed and producing power within 3 years. The feasibility of modifying the Southwest Brooklyn plant can be directly applied to similar modification of the Betts Avenue and Greenpoint facilities. In addition, the other three existing plants which are not in service could be refurbished and retrofitted as waste-to-energy facilities.

As a result of this study, the WESTON/Black and Veatch recommendation is that you proceed with preliminary engineering to; verify the plant design parameters and selection of materials, further identify environmental impact investigation required and extend the cogeneration concepts to include hot water district heating.

WESTON has analyzed a great many Resource Recovery Projects over the past 10-15 years. This project economically represents one of the best we have seen. We recommend that appropriate steps be taken to promptly initiate the preliminary engineering required to implement this economically and environmentally attractive project.

Very truly yours,

WESTON (a Business Trust)

Aw Hogeland
A. William Hogeland, P.E.
Project Director

Warren H Chesner
Warren H. Chesner, Ph.D., P.E.
Project Manager

AWH:WC/sle

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BLACK AND VEATCH

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The cover photo was provided by Skyview Surveys, Inc.

SECTION 1

EXECUTIVE SUMMARY

1.1 OVERVIEW

The Southwest Brooklyn Incinerator is one of six 1,000 ton per day (tpd) incinerators built by the City of New York in the 1950's. Of these six, only three are presently operating: Betts Avenue, Greenpoint, and Southwest Brooklyn. Each incinerator is equipped with four furnace trains, each designed to process 250 tpd of municipal refuse. The inoperative incinerators include: Hamilton Avenue, South Shore, and Gansevoort.

Both the heating value contained in municipal refuse, which can be converted into useful energy, and the material value of the refuse ash, which can be recovered and recycled into a useful product, offer an opportunity to convert the solid waste into a useful resource and product. The primary purpose of this investigation was to examine both the technical and economic feasibility of exploiting the heating value of the refuse and the material value of the incinerator ash processed at the Southwest Brooklyn incinerator.

Based on the results of field testing, the combustion of municipal refuse at Southwest Brooklyn would be capable of generating 2.2 trillion Btu of energy annually. Enough of this energy could be recovered to produce 93.8 million kWh of electricity, which could supply the annual needs of almost 17,000 homes, or produce 1.2 billion pounds of steam to satisfy the annual heating requirements of approximately 10,000 homes during the heating season.

Quenched incinerator residue is currently transported by barge to New York City's Fresh Kills sanitary landfill on Staten Island. On the basis of a review of market conditions for ferrous recovery and the utilization of incinerator residue as asphalt aggregate, the residue has a potential economic value capable of generating revenues of $1,000-$3,000/day. Materials recovery could offer the additional economic and environmental benefits associated with the reduction or elimination of barging the residue to Fresh Kills.

On the basis of the examination of both the technical requirements and the economics of recovering energy and materials from processed refuse presented in this report, the following conclusions were drawn:

1. The recovery of energy for electricity generation and/or electricity generation with steam production for district heating during the winter months is both technically and economically feasible, and appropriate action should be taken as soon as practical to plan for the preparation of construction contract documents for such an undertaking.

2. There exists an opportunity in the City of New York for the recovery of incinerator ash for use as asphalt aggregate in City-owned asphalt production facilities in Brooklyn. Further testing is required to verify the full potential of ash utilization. Plans for verification should also proceed as soon as practical. The recommended testing program is presented in subsection 10.3.

Plans for energy and/or material recovery at the Southwest Brooklyn Incinerator are especially attractive because:

1. The existing furnaces and structures represent a significant portion of the processing systems required for a new refuse-to-energy facility. It is estimated that energy recovery at a new refuse-to-energy facility would require a capital investment greater than twice that of the equivalent energy recovery facility at Southwest Brooklyn.

2. The existing facility eliminates the necessity for comprehensive siting investigations.

3. Local trucking routes have already been established.

4. Additional environmental impacts and licensing requirements are minimal.

5. Energy and material recovery feasibility demonstrated at Southwest Brooklyn can be directly applied to the other operating incinerators at Betts Avenue and Greenpoint, and may be applicable to those incinerators that are presently inoperative.

1.2 ENERGY RECOVERY

The technical feasibility associated with energy recovery from Southwest Brooklyn was evaluated by determining the following:

1. Heat content of the refuse, and the energy available for steam generation.
2. Requirements for the control of waste heat boiler corrosion problems.
3. Requirements for the integrated control of boiler/ turbine operation for electricity generation.
4. Available district heating market.
5. Total energy output.

A field testing program was undertaken in which flue gas quantities and temperatures were monitored to determine the heat available for steam generation. This eliminated the need to rely on literature values for the heat content of refuse to determine the energy available for steam generation. This testing program is presented in detail in Section 4.

A detailed review of potential corrosion problems, and mitigating measures, as well as the expected waste heat boiler operational life, was undertaken to determine process modifications and equipment requirements to minimize the impact of corrosion on heat recovery operation. This evaluation was undertaken by reviewing the literature for corrosion problems associated with municipal refuse combustion, site visits to facilities with dirty gas waste heat recovery applications, and discussions with both European and U.S. waste heat boiler manufacturers concerning operating experiences and recommended operating and design practices. This review is presented in Section 6.

A comprehensive review of boiler/turbine operation utilizing a fuel with the fluctuating heating value characteristics of municipal refuse was undertaken to ensure that compatible boiler/ turbine operation could be effected. This review was integrated into the control systems for the boiler/turbine operation presented in Section 6.

A market survey of potential energy users within a three-quarter mile radius of the incinerator was implemented to determine the available steam market. This survey is presented in detail in Section 5.

An energy availability model was constructed on the basis of energy and equipment availability, and the effect of wet refuse on energy output. On the basis of this analysis, the efficiency of the waste heat boiler and turbine output was projected. The availability model is presented in detail in Section 4, and energy output is presented in Tables 9-4 and 9-5.

The economic feasibility of energy recovery was addressed by comparing projected revenues against projected costs using revenue projections from New York State Power Pool projected electricity rate schedules and Power Authority (PASNY) projections of oil replacement costs for the steam rate schedule. This analysis is presented in Section 9.

Three energy recovery options were evaluated:

1. Generation of electricity only.
2. Cogeneration of electricity with steam distribution to all users within a three-quarter mile radius of the incinerator (full steam loop).
3. Cogeneration of electricity with steam distribution to selected users (partial steam loop).

The installed equipment (capital) cost in 1981 dollars, for each alternative is as follows:

1. Electricity only	$26,972,000
2. Cogeneration with steam distribution to all users	$53,082,000
3. Cogeneration with steam distribution to selected users	$32,309,000

Potential revenues associated with the electricity-only alternative, although less than either cogeneration option, yields the most favorable cash flow forecast (presented in Tables 9-6 through 9-10). Three deficit years are projected utilizing a rate structure that provides for electrical revenue rates at $0.0770 per kWh in 1986, and escalating thereafter in accordance with New York State Power Pool projections.

The cogeneration-to-selected-user alternative, using Power Authority revenue projections of $10.31 per 1,000 lbs in 1986, is the second most favorable option with only four years of deficit cash flow. This alternative will become more favorable as the area in the vicinity of the incinerator develops and the demand for district heating increases.

On the basis of a review of costs, revenues, and implementation requirements, detailed in Section 10, the electricity-only alternative was recommended for immediate consideration. It is also recommended that this system be designed with the flexibility to incorporate steam or hot water generation for future district heating purposes.

The project implementation schedule for licensing, engineering, and construction is presented on Figure 9-1.

1.3 MATERIALS RECOVERY

The recovery of ferrous metals from incinerator residue and the utilization of processed residue as aggregate material for bituminous paving mixtures were judged to be the two areas with the greatest potential for market penetration.

Market interest for recovered ferrous material has been expressed by members of the Institute of Scrap Iron and Steel in New York, as well as other ferrous metal dealers.

The New York City-owned Hamilton Avenue Asphalt Plant could provide a reliable market for asphalt aggregate. This plant has a design capacity of 7,200 tpd, as compared to the incinerator's residue generation rate of 200-300 tpd. Residue aggregate processed to specifications could be blended with natural materials for use in asphalt mixtures.

Both ferrous metal and residue aggregate could be recovered with little interference with existing operations. The incinerator residue could be diverted from the existing barge conveyors through rotating screens and magnetic separators to classify residue sizes and separate ferrous materials.

Two recovery concepts were investigated: partial recovery and total recovery.

The installed equipment (capital) cost in 1981 dollars for each option are as follows:

Partial recovery	$796,500
Total recovery	$945,500

On the basis of projections of aggregate replacement costs and/or ferrous resale, presented in Section 7, the partial recovery of ferrous and aggregate from incinerator residue is recommended for further investigation. This alternative could also be modified to provide for total recovery of residue at some future date. Material recovery marketing technical and economic evaluations are presented in detail in Section 7.

1.4 AIR POLLUTION CONTROL

The rehabilitation of the air pollution control equipment on furnace No. 1 would require a process train similar to those currently installed on furnaces Nos. 2, 3, and 4. This includes the installation of a new gas-conditioning tower and electrostatic precipitator. The capital cost associated with installation of the new equipment would be approximately $5,140,000, expressed in 1981 dollars. This cost is not incorporated into any of the three energy recovery options presented, but would have to be accomplished in order to ensure the selected option capacity available. A detailed analysis of air pollution control requirements is presented in Section 8.

1.5 RECOMMENDATIONS

It is recommended that the City of New York and the Power Authority of the State of New York proceed with plans for the design and construction of an energy recovery facility at the Southwest Brooklyn Incinerator. This facility should be capable of generating electricity year-round, but should also be designed with the flexibility to extract steam for district heating purposes in the future. It is recommended that these integrated facilities be administered by one management entity. Details of various operating arrangements are presented in Section 3.

Given the present district heating market at Southwest Brooklyn, generating electricity is most promising economic alternative. It also is the simplest to implement since it does not require the construction of a distribution system, or negotiations with potential steam customers. In addition, it has the flexibility to incorporate steam or hot water distribution in the future.

With increased development in the vicinity of Southwest Brooklyn, the economics of district heating, with its more efficient utilization of the heat value of the refuse, will become more favorable.

Additional steps which should be undertaken prior to the preparation of final design documents are presented in subsection 10.5.

Partial recovery of ferrous and aggregate from incinerator residue is a promising alternative worthy of additional consideration. The details of further investigation requirements are outlined in subsection 10.3 and 10.5. It is recommended that the material recovery component operate under the same management entity as the incinerator, but this is not essential, and an independent operation could exist for material recovery.

It is recommended that a fourth air pollution control train for furnace No. 1 be installed at Southwest Brooklyn to meet present air pollution control requirements and to provide the flexibility to operate the incinerator and the waste heat boilers independently if necessary.

A detailed presentation of the analysis of the various alternatives is given in Section 10.

SECTION 2

INTRODUCTION

A few years ago, inexpensive energy was available, and sanitary landfills were considered to be the most acceptable solution to solid waste management problems. Solid waste incinerators were being retired because they could not meet the more restrictive air pollution standards. Today, energy costs are rising, fewer convenient environmentally-acceptable landfill sites are available, and the cost of solid waste management is increasing. The use of combustion systems is again considered an attractive alternative for solid waste management, and for energy and material recovery.

Solid waste management planning in the City of New York has been affected by this national cycle. Of the six original 1,000 tpd incinerators, three have been closed. The Southwest Brooklyn and Greenpoint Avenue incinerators in Brooklyn, and Betts Avenue in Queens, remain functional after being refurbished and refitted with air pollution control systems. The major portion of the 22,000 tpd of solid waste generated in the City has been directed to City landfills. Recent steps taken by the City to reverse this trend include the proposed 3,000 and 1,740-tpd resource recovery facilities for the Brooklyn Navy Yard and the South Bronx, respectively. Included in this overall planning process is an evaluation of modifying existing New York incinerators to incorporate both energy and material recovery processes. This latter alternative is attractive for two major reasons:

1. The existing incinerators and structures represent a significant portion of the capital requirements associated with a refuse-to-energy facility.

2. The local community has already accepted the presence of the facilities, local transportation routes have been established, and additional environmental considerations would be minimal.

On 16 October 1980, the firm of Roy F. Weston, in association with Black & Veatch, contracted with the New York City Department of Sanitation (NYCDOS) and the Power Authority of the State of New York (PASNY) to perform a study investigating the feasibility of implementing a resource recovery program at the Southwest Brooklyn Incinerator. This study provided for an investigation of energy and incinerator residue materials recovery alternatives. The contract was amended to include a field-testing program at the incinerator.

This evaluation included an assessment of several energy and material recovery options, including electrical generation only, or the cogeneration of electricity and steam for district heating; and recovery of ferrous and nonferrous materials from incinerator residues.

In addition, the study included an evaluation of the requirements for renovating the air pollution control train on furnace No. 1 to meet air pollution control requirements. Furnaces Nos. 2, 3, and 4 were previously fitted with air pollution control equipment.

The remainder of this report is divided into the following sections:

- Section 3 -- Background and Design Objectives

  Reviews the existing operation at the Southwest Brooklyn Incinerator, the study goals, and the operating criteria for the proposed resource recovery facility.

- Section 4 -- Energy Availability

  Presents the methods and analyses undertaken for determining the potential energy available for recovery at Southwest Brooklyn.

- Section 5 -- Steam Market Analysis and District Heating Concept Design

  Identifies the potential steam market in the incinerator vicinity and presents options and costs for transporting the steam to nearby consumers.

- Section 6 -- Waste Heat Boiler and Turbine Concept and Cost

  Provides a feasible engineering basis and design for a cost evaluation of electricity and cogeneration concepts.

- Section 7 -- Materials Recovery

  Provides a review of the results of a residue market survey, and presents the engineering and design requirements associated with material recovery options.

- Section 8 -- Furnace No. 1 Air Pollution Abatement Recommendations

  Presents the requirements and costs for installation of the fourth air pollution control train on furnace No. 1.

- Section 9 -- Cost Evaluation

  Reviews and evaluates the costs and revenues associated with the options presented in Sections 5 through 8.

- Section 10 -- Analysis of Alternatives and Recommendations

  Summarizes the final recommended alternatives.

SECTION 3

BACKGROUND AND DESIGN OBJECTIVES

3.1 BACKGROUND

The Southwest Brooklyn Incinerator is located on Bay 41st Street, in Brooklyn, adjacent to Gravesend Bay (Figure 3-1). The facility, designed and built in the late 1950's, is equipped with four furnace trains, each designed to incinerate 250 tons of municipal refuse per day. All of the furnaces have since been refurbished, and three have been fitted with modern air pollution control trains. The incinerator is operated in conjunction with a marine transfer station (MTS) located on-site. Excess refuse and noncombustible materials are diverted to the MTS where it is loaded onto barges for transport to New York City's Fresh Kills Landfill on Staten Island.

The total quantity of refuse delivered to the incinerator and transfer station averaged 810 tons/operating day between November 1979 and October 1980. The design refuse load of 1,000 tpd was attained on only 16 percent of the operating days. During this period, however, modifications to the furnaces were being implemented, which reduced the availability of the equipment. The City has the capability to deliver sufficient refuse to attain the design load.(1,2) Appendix A presents data illustrating the annual distribution of delivered refuse, as well as the frequency distribution of these refuse quantities.

Municipal refuse received at the plant is weighed and deposited in the refuse pit. This pit has a nominal capacity to water level of 1,180 tons (based on a packer truck refuse density of 450 lbs/cu yd). Stacking the refuse, which is a normal operating procedure, increases the capacity to 2,200 tons or 2.2 days of design station throughput.

Refuse is charged to the furnaces by two overhead traveling cranes. The crane operators maintain a "plug" of refuse in each charging chute to prevent infiltration of outside air. Each charging chute is equipped with a thermostatically-controlled water jacket to prevent fires.

The furnaces are refractory brick sidewall and roof arch construction, and are equipped with reciprocating grate stokers. Each stoker consists of four grate sections with independent

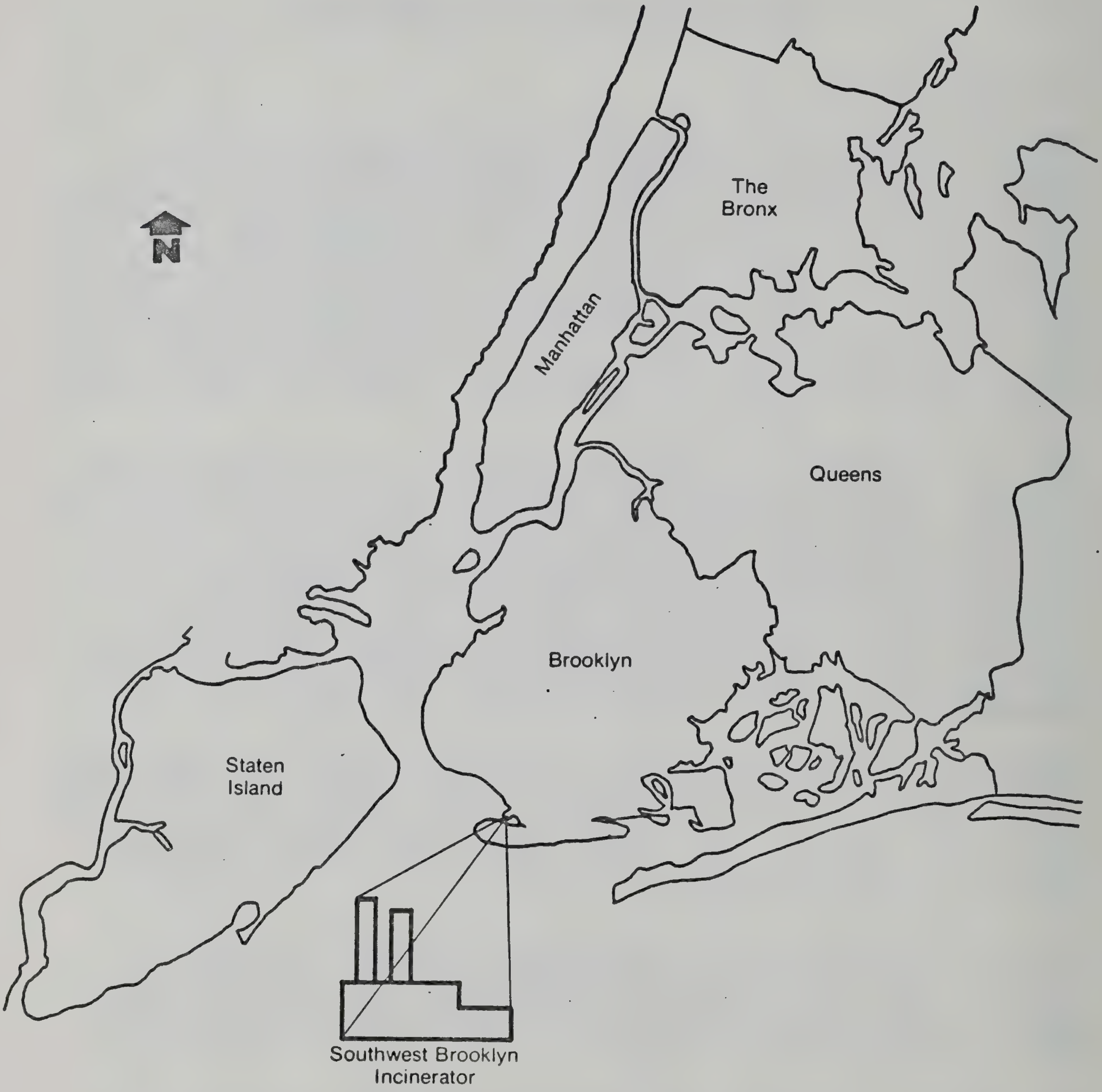

FIGURE 3-1 LOCATION MAP

speed controls. Refuse entering the furnace is continuously mixed and tumbled along the length of the stoker. The continuous mixing increases combustion efficiency and residue quality by spreading the refuse evenly and controlling the exposure of new materials to the flame. Residue from each furnace falls from the end of the stoker into a water-filled quenching trough. A series of drag flight conveyors is utilized to transport the quenched residue to the disposal barge.

Air is supplied to each furnace by three forced-air fans (underfire, overfire, and wall cooling) with design capacities of 24,700, 24,000, and 8,500 SCFM, respectively. Each fan operates at a constant speed; air flows are varied by means of variable-pitch intake dampers. The total air capacity of 57,200 SCFM represents approximately 260 percent excess air on the basis of fuel with a heating value of 4,370 Btu/lb, and a stoichiometric air requirement of 3.53 lbs air/lb refuse (see Appendix M).

Flue gas from the furnace passes into the secondary chamber which is designed to increase the retention time in the furnace for final gaseous combustion and fly ash deposition. The exit gases are presently routed through a bypass flue directly to the stack. When the air pollution control equipment becomes operable in the near future, the gases will pass through an outlet breeching into the air pollution control train. The existing air pollution control equipment is described in detail in Section 8.

The incinerator is presently operated on a six-day week; no refuse is received or incinerated on Sundays. Furnace fires are allowed to burn out on Saturday evening and are restarted early Monday morning. A detailed description of furnace startup and operating procedures is presented in Appendix N.

3.2 RESOURCE RECOVERY GOALS

The major objectives of this study were to evaluate the feasibility of energy and material recovery at the Southwest Brooklyn Incinerator, while maintaining the primary incinerator function, i.e., refuse combustion. Energy recovery offers an opportunity to utilize the heat value contained in refuse, which is presently wasted, to generate low-cost energy. Material recovery offers an opportunity to recover the economic value associated with the components of incinerated residue and to reduce or eliminate the economic and environmental problems associated with barging and landfilling the residue at Fresh Kills.

3.2.1 Energy Recovery

Two alternatives for energy recovery were evaluated:

1. Electricity generation.

2. Cogeneration of electricity with provision for steam district heating.

Concepts for both alternatives are presented schematically on Figure 3-2, highlighting major equipment components. The basic electrical concept utilizes the heat contained in the incinerator flue gas to generate steam which expands through a turbine to the condenser. The electricity and steam concept is analogous, except the process steam is extracted through a second heat exchanger to generate distribution system steam, reducing the quantity of steam available for generation of electricity.

3.2.2 Material Recovery

The feasibility of recovering recyclable materials from the incinerator residue was investigated to determine the marketability of recovered goods and the associated technical requirements, and economics of recovery. Specifically, the following materials were investigated (see Section 7):

1. Ferrous metals.
2. Nonferrous metals.
3. Aggregate materials (ferrous and nonferrous).

Concepts for material recovery are presented schematically on Figure 3-3.

3.2.3 Air Pollution Control

To operate the facility at the design throughput rate of 1,000 tpd, the incinerator must comply with air pollution regulations. Presently, furnace No. 1 is outfitted with the air pollution control equipment originally used in a preliminary testing program in the early 1970's. This equipment requires replacement in order to meet existing regulations.

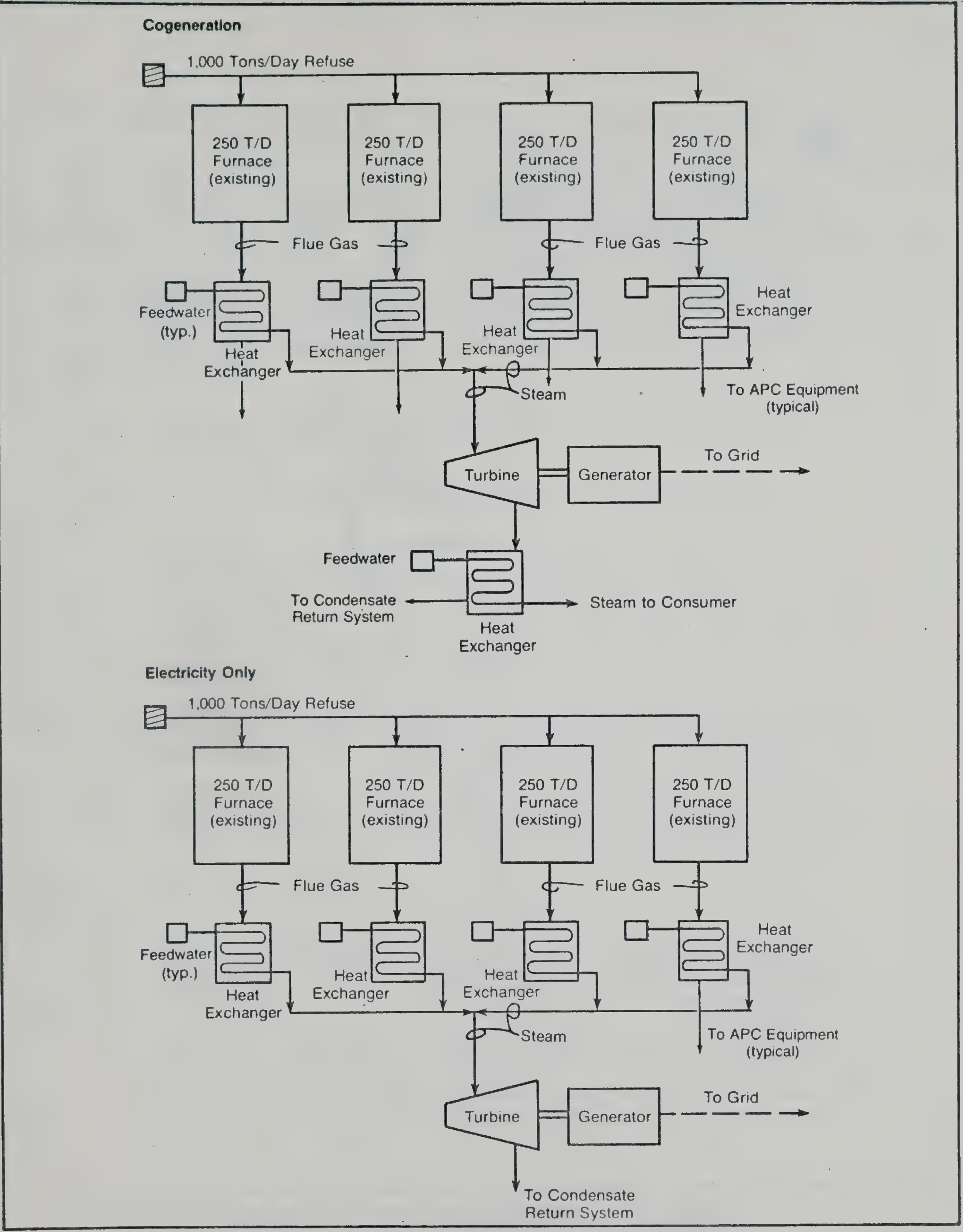

FIGURE 3-2 ALTERNATIVE ENERGY CONCEPTS

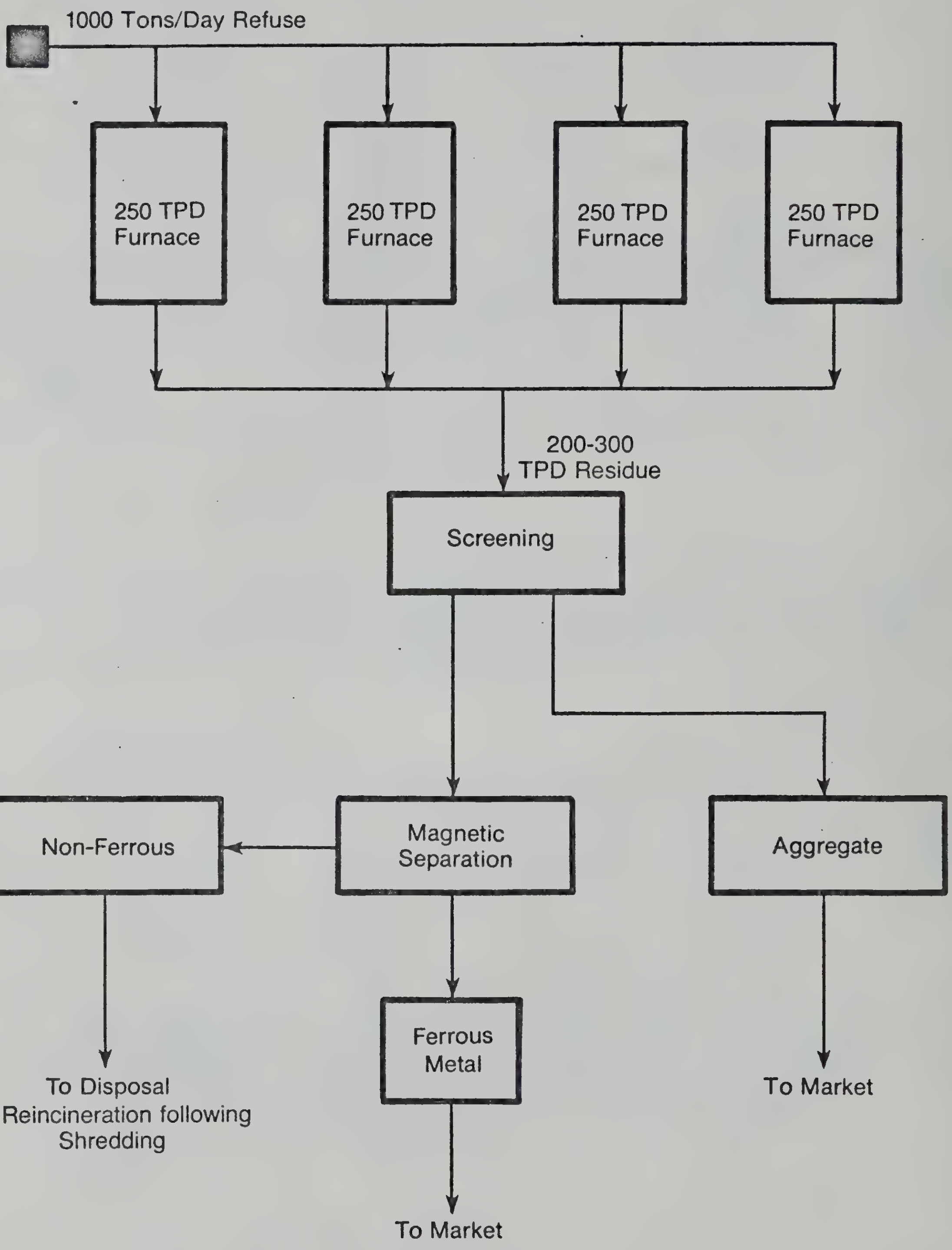

FIGURE 3-3 MATERIALS RECOVERY CONCEPTS

3.3 OPERATING GOALS AND CRITERIA

The primary goal of the existing Southwest Brooklyn Incinerator is processing refuse (i.e., refuse volume sterilization and reduction). Operation of the refuse processing facility as a resource facility will require new operating goals that focus on energy and/or material recovery, as well as refuse processing.

Subsection 3.3 suggests administrative requirements and new operating components that could be considered for the electricity only, steam and electricity, and the material recovery alternatives proposed.

It is recommended that a single administrative organization be responsible for the overall operation of the facility.

Five distinct operating components can be readily defined, depending on the nature of the facility. They include:

1. Furnace operation and maintenance -- The responsibilities include: refuse throughput control; waste gas temperature and volumetric flow control, as well as the maintenance of refuse weighing, storage, hoppers, furnaces, furnace fans, residue removal equipment, and building facilities.

2. Energy recovery operation and maintenance -- The responsibilities include: the operation of the waste heat boilers, turbine, and ancillary equipment.

3. Air pollution control train operation and maintenance -- The responsibilities include: the maintenance and operation of the gas conditioning towers, electrostatic precipitator, fans, and ductwork in the APC train.

4. Steam distribution system operation and maintenance -- The responsibilities include: the maintenance of all pipes, pumps, traps, valves, and ancillary equipment related to steam distribution.

5. Material recovery system operation and maintenance -- The responsibilities include: the operation and maintenance of conveyers, trommel screens, magnetic separators, and storage facilities for material recovery.

Each of these operating components would require interaction with other components. For example, the furnace operation would closely interact with the energy recovery operation, providing appropriate refuse throughput quantities and maintaining waste gas temperatures within a defined range. Some or all of these components may be combined into one or more operations. For example, the furnace, APC, and material recovery operations could be combined into one operation, with the energy recovery and steam distribution system a second operation. Any individual component could be further subdivided into smaller components. For example, the furnace operation could be subdivided into refuse weighing, storage and charging, and the furnace combustion and residue disposal operation. Any one of these operations may be contracted out for private operation, if desirable.

The incinerator would be base-loaded to operate at an approximate rate of 250 tpd/furnace (depending on fuel content), to maintain a relatively constant heat output. Table 3-1 summarizes each operating component, with respect to the appropriate alternative.

1. Electricity Production Only.

   Electricity production requires three operating components: furnace operation, energy recovery operation, and APC train operation. The furnace operators would be required to maintain throughput and waste gas temperatures within specified limits. The energy recovery operators would reduce the waste gas temperatures to specified APC equipment limits, extracting the waste heat for steam to electricity generation.

2. Steam and Electricity Production.

   For this alternative, the energy recovery operators would be required to supply main and/or extraction steam to a heat exchanger to meet district heating requirements. Heat supplied from the incinerator to the district would be used in lieu of existing heating systems. However, these systems would be retained for backup during periods of low incinerator steam production or downtime. Heat supplied to the district would be used to augment existing systems; no guarantee of heat supply would be provided to consumers. At times when heat is not required, all recovered energy would be used to produce electricity. In general, the same method of operation used in

Table 3-1

Operating Components for Various Resource Recovery Alternatives

Alternative	Operating Component	Responsibility
Electricity production	Furnace operation	Refuse throughput, waste gas temperature, waste gas flow rate, furnace and residue removal, operation and maintenance.
	Energy recovery operation	Waste heat boiler turbine-generator, condenser/cooling tower, operation and maintenance.
	APC train operation	Gas conditioning tower, electrostatic precipitator, operation and maintenance.
Steam and electricity production	Furnace operation	Same as electricity production and furnace operation.
	Energy recovery operation	Same as electricity production and energy recovery operation, with an additional heat exchanger.
	Steam distribution system operation	Maintenance of steam distribution system.
	APC train operation	Same as electricity production and APC train operation.
Material recovery (assume with electricity production)	Furnace operation	Same as electricity production and furnace operation.
	Energy recovery operation	Same as electricity production and furnace operation.
	APC train operation	Same as electricity production and APC train operation.
	Material recovery operation	Operation and maintenance of material recovery equipment.

electricity generation only would be used. This operation introduces one additional operating component, i.e., steam distribution system operation.

3. Material Recovery.

The total requirements of this option depend on whether any of the other alternatives are implemented simultaneously. Material recovery is an option which may be implemented independent of energy recovery operations. The material recovery operation assumes that the buyer will haul the material from the site as part of an agreement with the facility administrator.

SECTION 4

ENERGY AVAILABILITY

4.1 INTRODUCTION

The feasibility of waste heat recovery is based on a comparison of the revenues generated versus the capital and operating expenditures associated with the energy recovery equipment. Both revenue and equipment requirements are dependent on the quantity of energy which is available as a result of the combustion of the 1,000 tpd of refuse at the Southwest Brooklyn Incinerator.

The quantity of energy which can be recovered is a function of:

1. The energy contained in the combustion flue gases.

2. The availability and efficiency of the furnace and energy recovery equipment utilized.

The heat contained in the flue gases determines the total potential energy available; the reliability of the furnace and energy recovery equipment determines the relative amount of time that the equipment is on-line to extract the energy.

This section addresses in detail the steps utilized to define the heat value of flue gases and the energy available for recovery.

4.2 TOTAL HEATING VALUE

The total heating value of the combustion flue gases at the Southwest Brooklyn Incinerator is dependent on the combustion air temperatures and quantities. These conditions are dependent on:

1. Refuse composition and throughput rates.
2. Combustion air flow and infiltration.
3. Heat losses.

Two approaches were available to assess the total potential heat value of the incinerator flue gases. The first represents a theoretical approach which utilizes the heat content of the fuel, coupled with combustion air requirements as they relate to the total heat released to the flue gases. This approach requires numerous assumptions regarding the heat and moisture content of refuse and heat losses. The second approach involves the utilization of actual field data to define the total air flow and corresponding temperatures at various throughput rates in the existing furnace. This latter approach, which uses recorded data, was considered to be more reliable in defining actual design parameters at the facility. A comparison of the results obtained using these two methods is presented in subsection 4.2.3.

Plant records at Southwest Brooklyn were reviewed to determine the adequacy of existing data in defining the total heat available under actual operating conditions. It was concluded that the flow measuring devices installed in the overfire, underfire, and wall cooling air ductwork were inaccurate. In addition, no data were available which indicated the air infiltration through the furnace enclosure. For these reasons, a sampling program was performed during the week of 16-21 March 1981.

4.2.1 Field Sampling Program

The primary goal of the field program was to establish the total heat value of the flue gases leaving the secondary chamber at the design throughput rate of 250 tpd per furnace, defined by gas temperature and flow.

In addition, the field program offered an opportunity to monitor:

1. Temperature drops across the gas-conditioning tower.

2. Pressure drops across the existing air pollution control equipment.

Electrostatic precipitator specifications at the incinerator require a minimum gas entrance temperature of 400°F. This temperature ensures maximum particulate removal in the precipitator without the danger of dew point acid corrosion. Since the exit gases from the waste heat boiler will pass through the existing gas-conditioning tower, the anticipated temperature drop across the gas-conditioning tower defines the waste heat boiler exit gas temperature, and in turn, the total energy available for extraction.

The pressure drop across the existing air pollution control equipment, added to the anticipated pressure drop resulting from installation of the new waste heat boiler, defines the total system pressure drop and induced-draft fan design requirements.

Implementation of the field program was accomplished by monitoring refuse throughput, air temperatures and flow rates, and conducting ORSAT analyses at selected locations. Detailed descriptions of the objectives, procedures, sampling locations, and results associated with each task are presented in Appendix B. Individual tasks included:

1. Calibration of refuse throughput rate with grate speed.
2. Measurement of forced-air flow rates from three forced-air fans.
3. Measurement of air temperatures in secondary chamber.
4. Calculation of secondary chamber flow rate.
5. Measurement of total stack gas flow rates.
6. Measurement of temperature drop across gas-conditioning tower at measured flow rates.
7. Pressure drop measurement across the air pollution control train.

4.2.2 Results and Conclusions

4.2.2.1 Flue Gas Heating Value.

A summary of the results of forced-air flow rates and secondary chamber temperature measurements for each test condition is presented in Table 4-1. Figure 4-1 is a graph plotting monitored forced air versus refuse throughput. The line drawn through the data represents the operating conditions at which the excess air and refuse throughput were set at conditions where residue was well burned out and the location of the fire on the refuse bed was well controlled.

Table 4-1

Results of Flue Gas Heat Value Testing Program
Furnace No. 2, Southwest Brooklyn Incinerator
(16-21 March 1981)

	Refuse Throughput		Air Flows SCFM			
Date	Buckets/ Hour	tpd[1]	Total Forced Air	Stoichio-metric[2]	Excess Air %	Temperature Secondary °F
3-16	6	165	28,500	10,600	170	1,228
3-17	9	248	42,800	15,900	170	1,345
3-18	10.6	292	NP	18,700	--	1,840
3-19	6.4	177	37,300	11,300	230	1,120
3-20	10.4	288	41,900	18,500	125	1,520
3-21	12.5	345	39,200	22,100	75	1,590

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[1] Calculated using 1.15 tons/bucket (average weight).

[2] Calculated using 3.53 lbs air/lb refuse.

NP = Not performed.

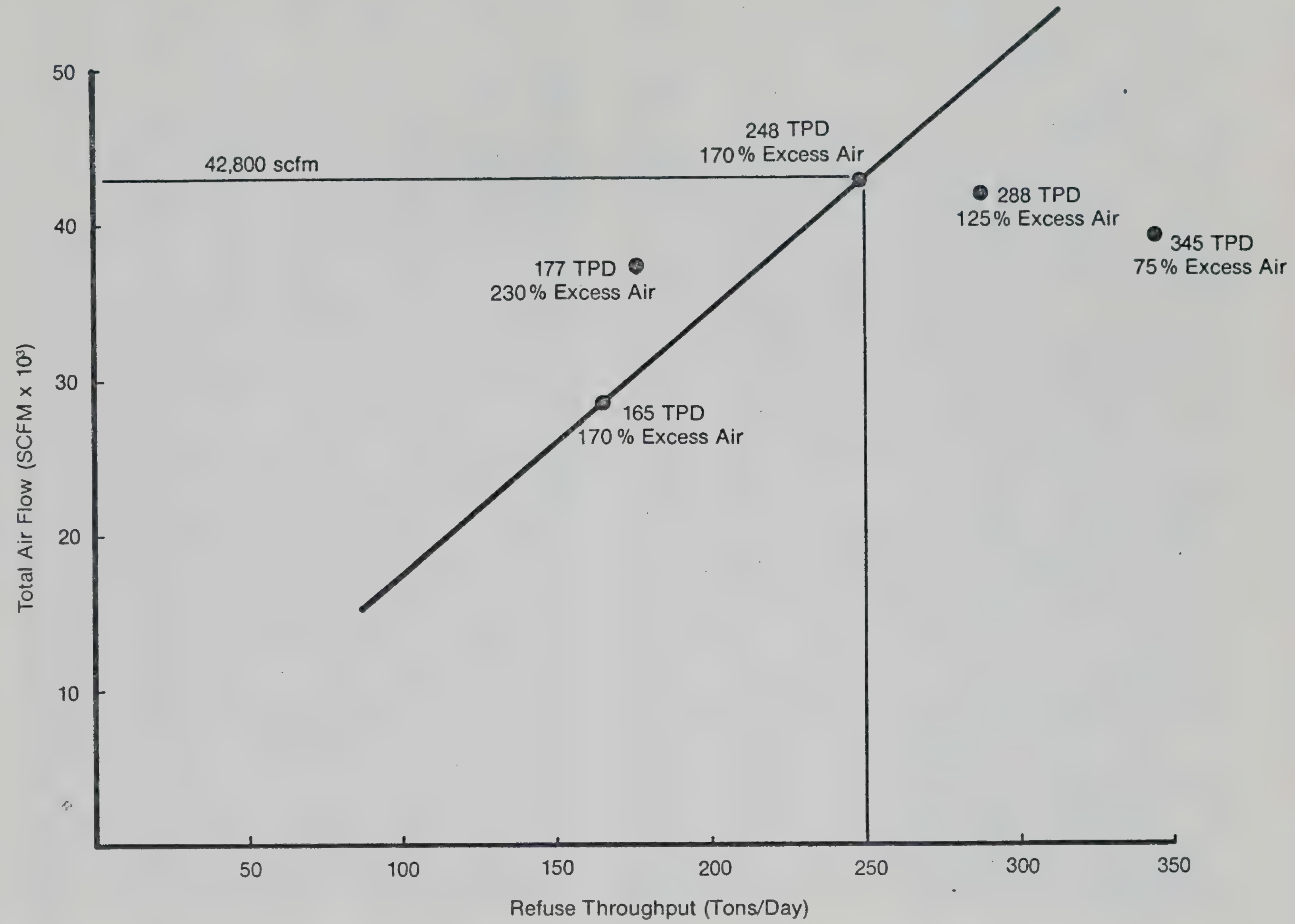

FIGURE 4-1 TOTAL AIR FLOW vs REFUSE THROUGHPUT SOUTHWEST BROOKLYN FURNACE NO. 2

The degree of burnout was determined visually by examining the residue at the furnace observation port below the "doghouse" and at the exit of the quench trough. Residue was inspected for the presence of partially-burned newspapers, labels remaining on metal cans, and citrus fruit peels. As a rule-of-thumb, the presence of these materials generally indicates less than optimum combustion efficiency in the furnaces. The data points, defining the line, represent data monitored on 16-17 March, with throughput rates of 165 and 248 tpd, respectively. Measured secondary chamber temperatures for each respective test were 1,228°F and 1,345°F, with 170 percent excess air calculated using 3.53 lbs air/lb refuse as the stoichiometric requirement (see Appendix M for derivation).

Data for 20-21 March, with throughput rates above 250 tpd, resulted in higher recorded secondary chamber temperatures of 1,520°F and 1,590°F, at 125 percent and 75 percent excess air, respectively. At these conditions, the refuse bed was burning too far down the grate, and there was an inordinate amount of combustibles remaining in the residue.

Data for 19 March, with a 177-tpd throughput, resulted in lower recorded secondary chamber temperatures of 1,120°F with 230 percent excess air.

On the basis of monitored and observed conditions, recommendations for incinerator operation are those which are presented by the straight line. As shown on Figure 4-1, the projected total forced-air throughput at a refuse processing rate of 250 tpd is approximately 42,800 SCFM. The existing underfire air fan can provide a maximum of approximately 51 percent of this flow. Modifications to the existing underfire air fan, proposed in subsection 6.2.5, will provide the means to increase the percentage of underfire air at the design conditions. Analysis of operating records indicate that secondary chamber temperatures of 1,500°F are not uncommon; the plant is required under New York State Department of Environmental Conservation (NYSDEC) regulation to attain a temperature of 1,400°F in the secondary chamber.[1] Therefore, a secondary chamber temperature of 1,400°F (at a total flue gas flow of 42,800 SCFM) was selected as the design point for the heating value of the furnace flue gases. This corresponds to a total flue gas heat input of 205 million Btu/hr, with all four incinerators operating at 250 tpd.

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[1] 6NYCRR, Part 222.4.

4.2.2.2 Gas-Conditioning Tower Temperature Drop.

Data collected for the operation of the gas-conditioning tower indicated that the passage of flue gases through the tower with the sprays not in operation would result in a temperature loss of approximately 90°F. Based on the minimum operating temperature of the electrostatic precipitator of 400°F, exit gases from the waste heat boilers would have a minimum temperature of 490°F. In order to maximize waste heat recovery, it was decided to limit the temperature drop across the gas-conditioning tower to 50°F. It was calculated that this would require a minimum of 1/2 inch of external mineral wool insulation on the gas-conditioning tower and uptake flue breeching. Calculations for heat loss and insulation requirements are summarized in Appendix C.

4.2.2.3 System Pressure Drop.

Results obtained from the pressure analysis indicated a total pressure drop of approximately 3.6 inches water across the system (induced-draft fan inlet to furnace). The pressure losses across each piece of process equipment are listed in Appendix B. This will necessitate increased induced-draft fan static pressure to overcome the total anticipated system losses.

4.2.3 Theoretical Energy Availability

A calculation of the theoretical energy available from the combustion of municipal refuse at Southwest Brooklyn is presented in Appendix K. Based on this calculation, the total heat available is 191 million Btu/hr, as compared with the actual measured value of 205 million Btu/hr. The difference between these values may be attributed to the numerous assumptions required in the theoretical calculation, including the amount of heat lost through the furnace enclosure, the specific heat and temperature of the residue and fly ash, and the heating value of the refuse itself.

4.3 ENERGY AVAILABILITY MODEL

The results of the field flue gas sampling program indicated that the energy available for design considerations, at 250 tpd of refuse throughput, is that which is contained in the combustion gases at a gas temperature of 1,400°F and a flow rate of 42,800 SCFM per furnace. The energy which can be utilized is that which can be recovered between 1,400°F and 450°F. The lower limit results from the 400°F electrostatic precipitator inlet requirement and the 50°F loss in the gas-conditioning tower duct. An alternative set of design conditions involves the use of boiler exit gas (at 450°F) to attemporate the inlet gases to 1,200°F. Under these conditions, 11,400 SCFM will be recirculated from the exit of each boiler to the uptake flue and mixed with 1,400°F flue gases. The resulting admixture, 54,200 SCFM at 1,200°F, will be reintroduced to the waste heat boiler system. Steam generation rates for this modification are slightly less than the nonrecirculation alternative.

Using this technique, only the waste heat boiler size had to be increased to handle additional gas flow. Flow rates to the gas conditioning tower and electrostatic precipitator remain unchanged.

Two items which can also influence energy availability are wet refuse and air preheating. Wet refuse can reduce the energy output since more heat is lost to water vaporization. Air preheating can increase the energy output by increasing the energy input, provided the energy used for preheating the air cannot be used more efficiently at another point in the cycle. Assuming 365 days per year of continuous operation, and including the effects of wet refuse and air preheating, the energy available for generation of electricity or cogeneration of electricity and steam can be calculated. The equipment, however, is not in working condition 365 days per year. The reliability of the recovery equipment will thus affect the total energy extracted.

To establish the total energy output, an energy availability model was developed. The model defines the total energy output available for electricity or steam generation, accounting for the effects of wet refuse, air preheating, and equipment reliability.

4.3.1 Wet Refuse

Wet refuse presents a problem to all plants that incinerate municipal wastes whether the plant generates steam using waste heat boilers or not. Typically, municipal refuse has a moisture content of 20 to 35 percent. After periods of significant rain or snow, the moisture content can increase substantially, depending on several variables such as the duration of the rainfall, whether the refuse was covered or not, how long the refuse was exposed, etc.

Operating records at Southwest Brooklyn show that after periods of heavy rain, both the incinerator burn rate and primary combustion temperature decrease. The present mode of operation with wet refuse is to slow down the first grate (underfire air grate/drying grate) and to speed up the remaining grates. This decreases the amount of refuse burned, and attempts to maintain the combustion temperatures by "spreading out" the refuse along the grates.

The air flow into the incinerator is also regulated to maintain the temperature in the incinerator. Air flows can be adjusted manually, or automatically in the case of the underfire air. It is anticipated that this mode of operation will continue if the incinerators are modified to produce steam using waste heat boilers. The primary concern, from an energy recovery perspective, is to maintain the incinerator temperatures and combustion gas flow rates.

The influence of wet refuse was evaluated by the following independent techniques:

1. A review of rainfall versus operating furnace temperatures at the Southwest Brooklyn and Betts Avenue Incinerators.

2. Telephone interviews with personnel at other incinerator facilities that generate steam.

3. An evaluation of additional oil-firing requirements at the Betts Avenue Incinerator during rainy periods.

Appendix D contains a detailed presentation of analysis procedures and results.

A preliminary review of 1980 operating records of furnace No. 2 at Southwest Brooklyn indicated that secondary chamber temperature readings fluctuated greatly; on several occasions, low secondary chamber temperatures ($<1,000^{o}F$) were recorded on days of or days following rainfall in excess of 1.5 inches. A direct relationship could not be developed between precipitation and secondary temperature due to the interaction of many parameters (i.e., refuse delivery schedule, forced outages, etc.), and the lack of a comprehensive, long-term data base.

Operating records at Betts Ave. (furnace temperature circular charts) were reviewed, as indicated previously, and provided an indication of the same general trend. On days when wet refuse was noted by stationary firemen and engineers, furnace temperatures were generally depressed.

Several telephone surveys were made to determine the influence of wet refuse on the operations at existing plants that burn refuse to produce steam. Operators at the Northwest Chicago, Illinois; Harrisburg, Pennsylvania; and Saugus, Massachusetts incinerators were contacted.

The Chicago plant experienced a decrease in steam generation from 110,000 lbs/hr to 60,000 lbs/hr when wet refuse (collected after 2-3 inches of rain) was burned, or approximately a 50 percent decrease in heat availability. At the Chicago plant the refuse throughput is slowed down, and the gas temperature is maintained as close to design as possible. Their experience is that proper operating temperatures can be maintained for light rainfalls by slowing the grate speed and fuel feed rates to allow the excess moisture to evaporate before reaching the portion of the grate where combustion occurs. With rainfalls greater than 2 inches, the wet refuse remains in the pit for several days in order to allow the water to drain out. Operators at Harrisburg and Saugus did not report any significant problems with wet refuse. The Harrisburg plant burns municipal solid waste and some commercial waste. The Saugus plant has a very large furnace with a preheating area for refuse. Telephone survey memoranda for these plants are contained in Appendix D.

A detailed evaluation of the operating records of the Betts Avenue Incinerator was undertaken. The analyses included correlations of steam generation, oil consumption, and refuse burn rates with respect to ambient temperatures and rainfall amounts for the period November 1976 through December 1979. The results of these analyses are presented in detail in Appendix D. The results of the evaluation indicate a heat loss of approximately 20 percent when burning wet refuse as compared to dry refuse.

From the evaluations and phone surveys, the amount of heat loss due to wet refuse was estimated. The procedure utilized included levelizing the heat loss over the year. The heat loss due to burning wet refuse was assumed to be 50 percent for rainfall amounts greater than 1/2 inch. This 1/2-inch rainfall value and 50 percent heat loss are both conservative, since the selected rainfall is lower than amounts which were observed to cause noticeable heat losses, and a 50 percent heat loss was greater than amounts observed or reported.

Weather data compiled by NOAA for the New York City area were obtained and analyzed to determine the incidence of rainfall in excess of 1/2 inch. During the period October 1976 through November 1980 there were 113 days on which the daily rainfall was 1/2 inch or more. These occurrences were slightly more frequent in the spring and fall than in the summer and winter months. The annual average for the period examined was 28 days. It was further assumed that the probability that the refuse would actually be exposed to rain would be approximately half the time. It was therefore conservatively estimated that the refuse is exposed on the street 12 hrs/day. Based on this methodology, a 50 percent heat loss would be incurred, 3.8 percent of the time (28 days per year times 12 hours per day). This value represents a total levelized heat input loss of 1.9 percent (0.5 x 3.8) over the entire year. During actual operations, there is the possibility that a 50 percent heat loss will be incurred during certain rainfall periods. Since the data base does not allow an adequate prediction of the heat loss during these periods, they are not addressed directly in the energy availability model. Based on these criteria, the total absolute influence of wet refuse is included by decreasing the total energy available by 1.9 percent over the entire year.

4.3.2 Air Preheating

Reported estimates(4) have indicated that at the design throughput of 250 tpd, the use of 250°F (as opposed to 70°F) underfire air can increase the output of the steam generators. This increase is based on taking credit for the increased heat input into the boiler.

Flue gas-to-air regenerative heat exchangers were studied and found to be unattractive for preheating because of their expense, the extensive ductwork required, and the incidence of plugging reported at other installations. Steam coil heaters were found to be the most compact, effective method to preheat the underfire air. The steam coils would be located inside the existing underfire air duct with a minimum amount of retrofit construction. The air side pressure drop across the coils requires installing larger underfire air fans on each unit. Steam for the heaters would be drawn from the deaerator extractor piping. Approximately 15,000 lbs/hr of steam would be extracted to preheat the air for all four incinerators when refuse moisture content exceeds 30 percent, followed by a corresponding drop in refuse heat content (refer to Appendix O, telephone memorandum from Black & Veatch to U.O.P., 25 March 1982).

Contacts with the manufacturer of the reciprocating grates installed at Southwest Brooklyn revealed that conclusive data are not available to determine the influence of preheated air on grate stability and operating life.(5) The preheat temperature, however, is well below the design temperature of the stoker components (bearings, etc.).

For operational flexibility, underfire air preheaters have been included in the proposed design to help maintain the design temperature during periods of wet refuse. However, since the actual benefit gained using preheated air is not adequately substantiated, for conservative reasons any increase in steam generating capacity was not included in the model.

4.3.3 Equipment Outages

This subsection summarizes the approach used to determine the equipment outages, and total hours of operation. Present plant operation is a 5 1/2-day incineration cycle with no refuse fed or burned from mid-Saturday through Monday morning. The resource recovery concepts presented in this report are based on a 24 hrs/day, 7 days/week, 52 weeks/yr operation. The basic plant components were identified in order to establish the number of components that significantly impact the plant operation. Figure 4-2 is a simplified flow diagram which shows the components included in the outage model and their availabilities.

Based on their maintenance experience, the Department of Sanitation has indicated that each incinerator will be available 75 percent of the year. The projected maintenance schedule indicates that each incinerator will be shut down every fourth Monday for routine maintenance and for an additional 45-day period each year for major overhauls.(6) The remainder of the projected incinerator outages are conservatively estimated to account for unscheduled maintenance. This number is consistent with outage records for the Greenpoint Plant (83.6 percent availability) for July 1962 through June 1969, and with 1980 operating data for incinerator No. 2 (81.9 percent availability) at the Southwest Brooklyn plant. Therefore, it is reasonable to expect that the availability of each incinerator and waste heat boiler will be at least 75 percent.

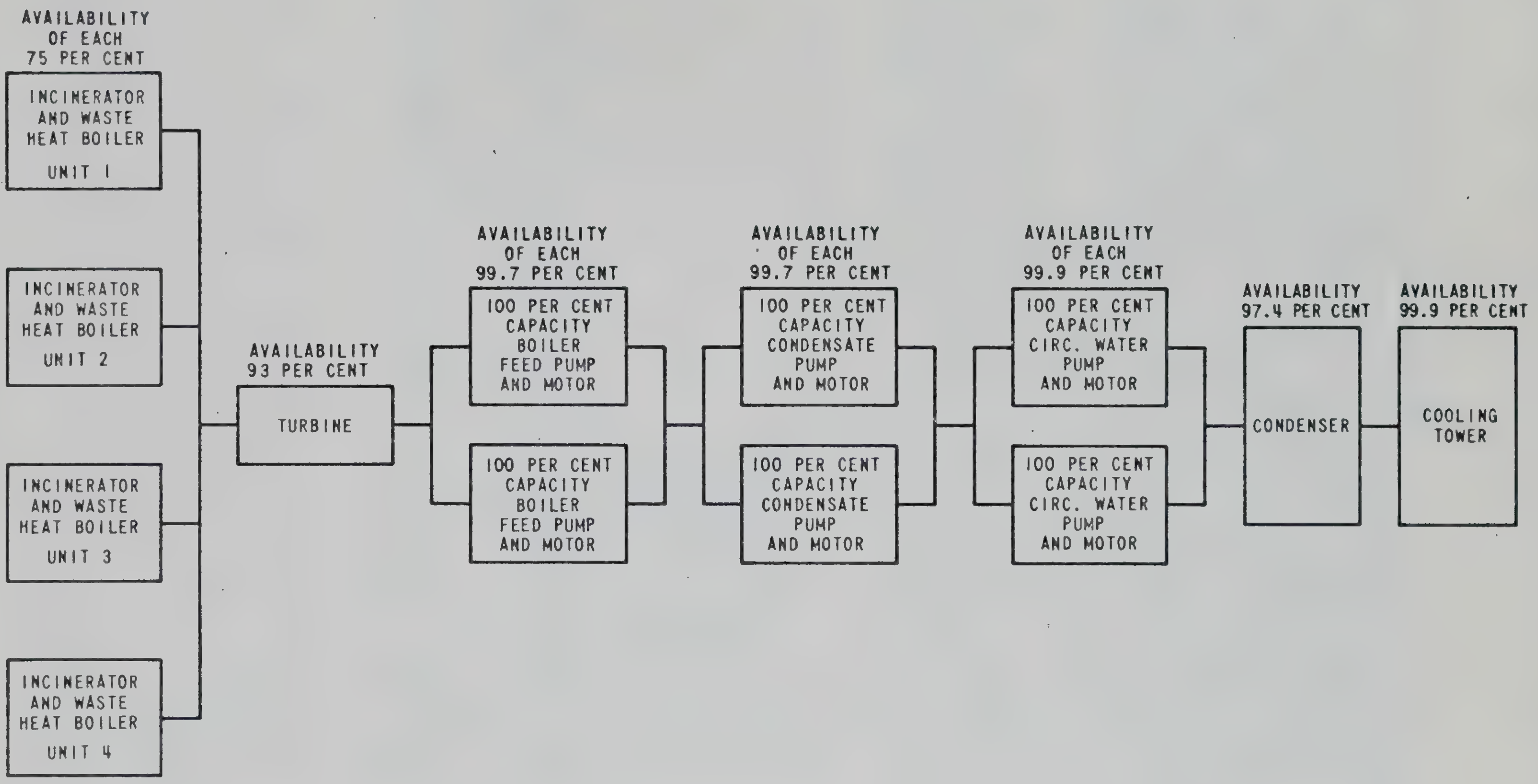
AVAILABILITY OF EACH 75 PER CENT
INCINERATOR AND WASTE HEAT BOILER UNIT 1
INCINERATOR AND WASTE HEAT BOILER UNIT 2
INCINERATOR AND WASTE HEAT BOILER UNIT 3
INCINERATOR AND WASTE HEAT BOILER UNIT 4
AVAILABILITY 93 PER CENT
TURBINE
AVAILABILITY OF EACH 99.7 PER CENT
100 PER CENT CAPACITY BOILER FEED PUMP AND MOTOR
100 PER CENT CAPACITY BOILER FEED PUMP AND MOTOR
AVAILABILITY OF EACH 99.7 PER CENT
100 PER CENT CAPACITY CONDENSATE PUMP AND MOTOR
100 PER CENT CAPACITY CONDENSATE PUMP AND MOTOR
AVAILABILITY OF EACH 99.9 PER CENT
100 PER CENT CAPACITY CIRC. WATER PUMP AND MOTOR
100 PER CENT CAPACITY CIRC. WATER PUMP AND MOTOR
AVAILABILITY 97.4 PER CENT
CONDENSER
AVAILABILITY 99.9 PER CENT
COOLING TOWER

FIGURE 4-2 AVAILABILITY MODEL DIAGRAM FOR PLANT

To increase the availability of the energy recovery system, redundant equipment arrangements are recommended for the steam generation equipment and balance of the plant portions of the facility. The proposed design of the condensate pump, boiler feed pump, and circulating water pump systems each include two full capacity pumps in order to ensure continued plant operation without incurring unreasonable capital expenditures. These pumps are critical to the operation of the steam plant. Therefore, duplicate full-capacity pumps are included. The availabilities shown for all of the other equipment were based on Edison Electric Institute and Nuclear Plant Reliability Data System information for similar size equipment.

The availability of each component is based on the probability that the equipment will be operational at a randomly-selected future point in time. Overall system availability for various relative energy outputs, defined by the system arrangement in Figure 4-2, are as follows:

	Percent of Time
Zero energy output	10
25% energy output	4
50% energy output	19
75% energy output	38
100% energy output	29

The calculations associated with this analysis were performed in accordance with the IEEE "Guide for General Principles for Reliability Analysis of Nuclear Power Generating Station Protection Systems," IEEE standard 352-1975 (ANSI N41.4), and are presented in Appendix E. An analysis of total annual refuse throughput, based on furnace availability, is presented in Appendix E, Table E-2. It is anticipated that approximately 240,000 tons/yr of refuse will be incinerated.

Scheduled maintenance of the equipment can be planned in order to minimize the impact on plant operations and the number of personnel required. For example, the Department of Sanitation contemplates the aforementioned routine maintenance and major overhaul schedule. The other plant equipment can be maintained on a schedule similar to the one contemplated for the incinerators. Therefore, the availability model takes into account all expected scheduled maintenance as well as forced outages. The total plant outages are levelized throughout the year in the energy availability model.

4.3.4 Energy Availability Model

The energy availability model for the plant can be determined from the energy availability estimates and the anticipated equipment performance. The model is shown on Figure 4-3. The model represents the total amount of heat that can be supplied by the waste heat boilers, based on the design conditions of 42,800 SCFM of flue gas per furnace, and 1,400°F boiler input and 450°F output temperatures. Alternatively, the model is also representative of inlet boiler conditions of 1,200°F at 54,200 SCFM, with an exit temperature of 450°F.

The model takes into account the effect of burning wet refuse, but does not include the additional heat input available when the underfire air is preheated. The levelized heat input loss of 1.9 percent attributed to wet refuse lowers the maximum energy available from 205 to 201 million Btu/hr. The four levels of heat output represent the number of incinerators and waste heat boilers that are operating. The hours of operation at each heat output are based on availability calculations as summarized previously in subsection 4.3.3. The model is shown with four discrete heat output levels since it is anticipated that each incinerator will either be operated at the design of 250 tpd, or will be out of service. The use of four discrete heat outputs also simplifies the electricity and steam-generating capacity estimates. During actual plant operations, the energy availability will be a continuous curve based on variances from the design temperature and air flow. The energy availability model as shown is, however, a realistic estimate of the average annual heat outputs and durations, and is based on conservative assumptions.

Using the availability assumptions just presented, the incinerator facility will process 273,750 tons of refuse per year.

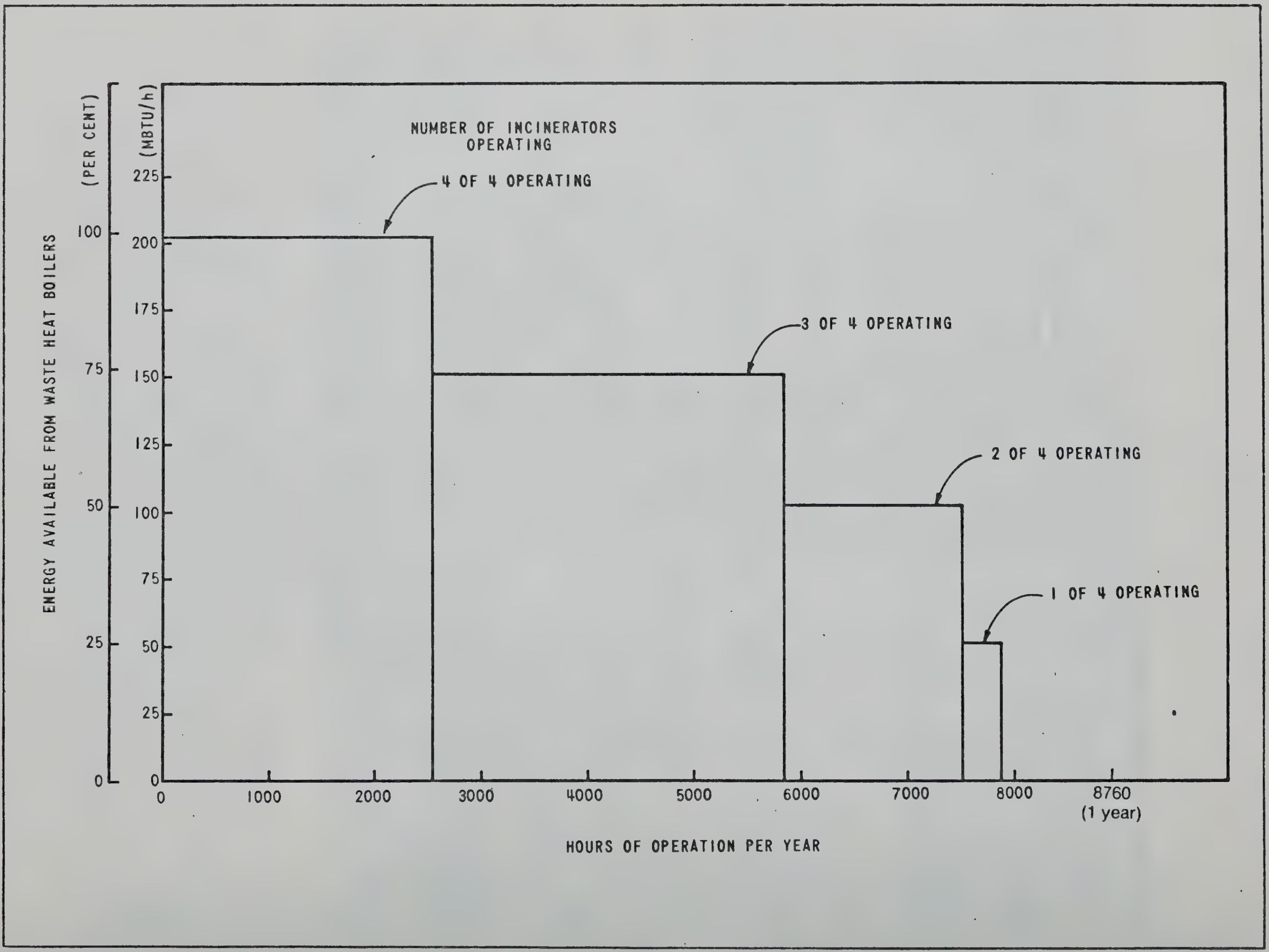

FIGURE 4-3 ENERGY AVAILABILITY MODEL

SECTION 5

STEAM MARKET ANALYSIS AND DISTRICT HEATING CONCEPT DESIGN

5.1 MARKET STUDY AREA

The area surrounding the Southwest Brooklyn Incinerator is comprised mainly of residential units with some commercial establishments. Land use in the study area (defined by a 3/4-mile radius from the incinerator) is estimated to be 50 percent residential and 25 percent commercial. The remaining area may be classified as municipal, comprised mainly of the Dreier-Offerman Park. The study area is bisected by a section of the Belt Parkway; all of the residential units addressed in this study lie on the opposite side from the incinerator complex.

The residential area is currently zoned R4, R5, and R6 which allows medium- and high-density housing. A small percentage of this area is zoned C8-1 for light commercial establishments. The area including and immediately to the north of the incinerator complex is zoned M3-1 and is available for heavy industry such as foundries, power plants, or chemical manufacturing. The area to the south is zoned M1-1, which allows lighter industrial establishments, and C3, which is a commercial zone (Figure 5-1).

5.2 MARKET SURVEY

Consultations were held with the New York City Planning Board and Community Board No. 11 to identify and locate suitable consumers of significant quantities of energy. The heating requirements of large apartments and institutions were obtained primarily by telephone interviews with maintenance personnel and/or management. A windshield survey was also performed within the study area to identify any additional establishments which might have been overlooked. Heating requirements for private residences were obtained from local oil suppliers and Brooklyn Union Gas Company. The Brooklyn Union Gas Company also provided detailed statistics on the number of residences in the area, and the heating requirements for various types of homes.

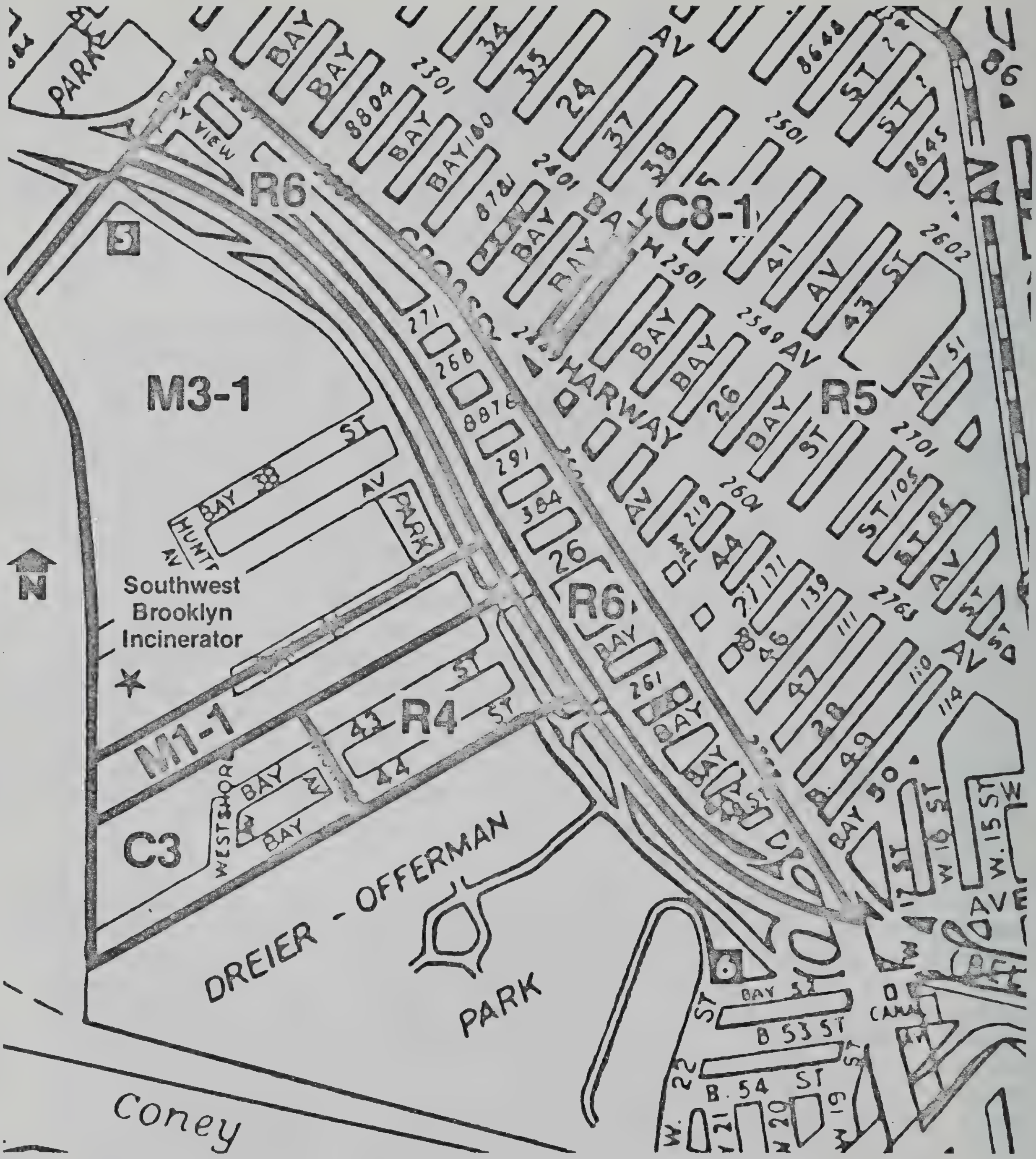

FIGURE 5-1 STUDY AREA ZONING MAP

Energy consumers identified within the study area were divided into three categories:

1. Major consumers -- All establishments with an annual energy consumption greater than 10,000 million Btu.

2. Intermediate consumers -- Residences and establishments with annual heating requirements between 800-10,000 million Btu.

3. Private residences -- Lower density housing (less than 16 residences per building) with an annual heating requirement less than 800 million Btu.

A summary of the total annual heating requirements for the study area is presented in Table 5-1. Significant energy consumers from all categories are shown on Figure 5-2.

5.2.1 Major Consumers[1]

Major consumers were defined as establishments in the area with a space heating requirement in excess of 10,000 million Btu/year. The 10 major consumers described in this subsection and listed in Table 5-2 represent approximately 41 percent of the study area heat load, or 5 percent of the total heat output of the incinerator.

Contello Towers

Location: 2600 Cropsey Avenue
Map reference No.: 1
No. residents: 1,850
Type fuel: Oil
Type heating system: Steam
Annual heating requirement (million Btu): 66,200

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[1] Subsequent to the completion of this report, construction of a 162-unit condominium complex was begun in the R4 zone, approximately 1/4-mile southeast of the incinerator. In addition, a large new car dealership was completed on Shore Parkway, adjacent to the entrance to the incinerator. The annual heating requirements and district heating load duration curves presented in this report do not include these additional loads.

Table 5-1

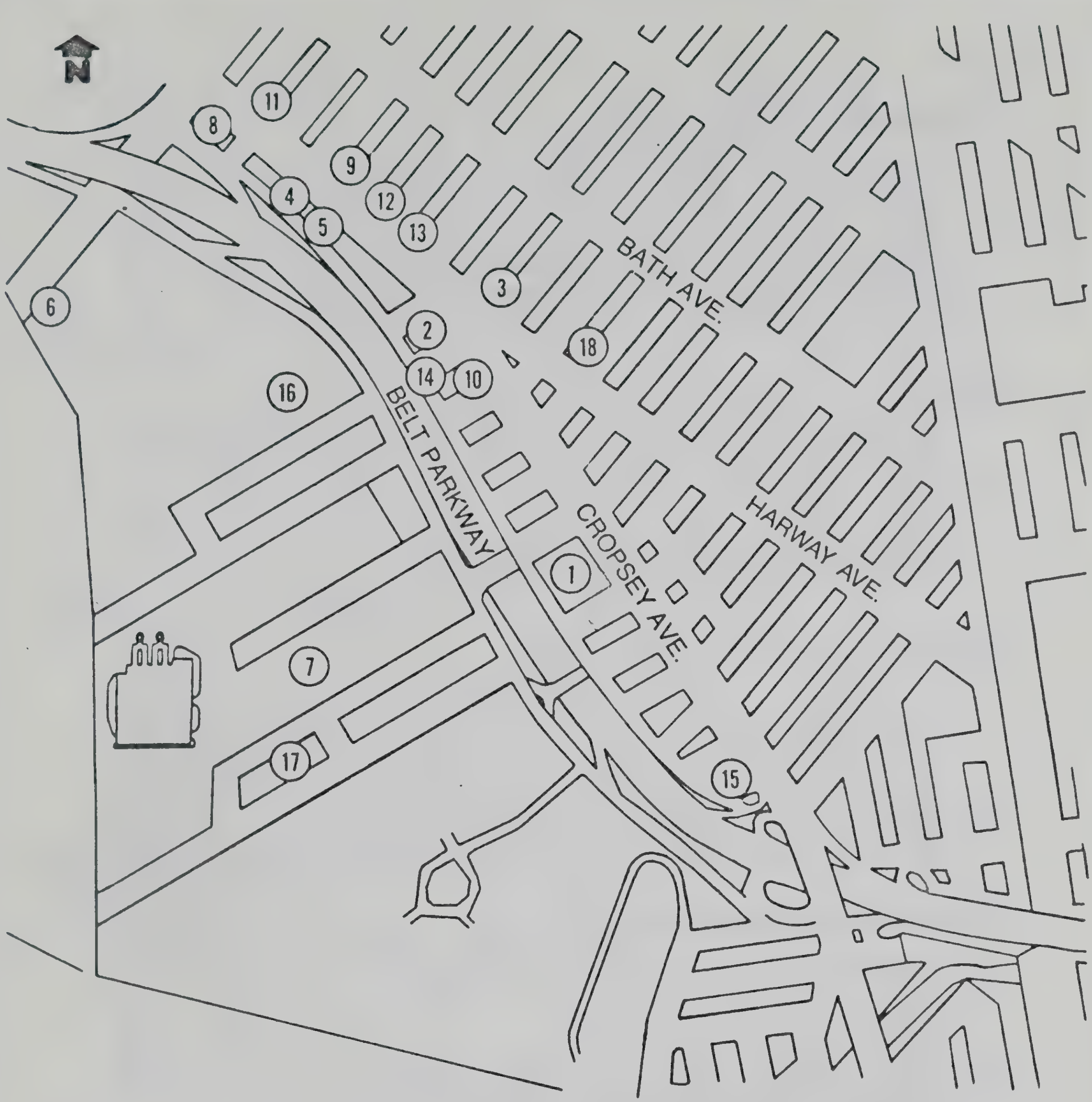
Total Annual Heating Requirements in Study Area

Consumer Group	Annual Heating Requirements million Btu
Major consumers	200,600
Intermediate consumers	46,180
Private residences	248,150
Total	494,930

Table 5-2

Major Energy Consumers in Study Area

Location	Annual Heating Requirements million Btu
Contello Towers	66,200
Regina Pacis Residences	10,100
JHS 281	15,400
Sephardic Home	24,400
Lawson Institute	11,200
Korvette's	11,000
Sanitation Garage	18,000
Bus Garage	20,000
Fountainbleu Apartments	13,100
Oxford Apartments	11,200
Total	200,600



1. Contello Towers
2. Regina Pacis
3. JHS 281
4. Sephardic Home
5. Lawson Institute
6. Korvette's
7. Sanitation Garage
8. Fountainbleu Apts.
9. Bayview Manor
10. Oxford Apts.
11. 2213 Cropsey Ave.
12. 8835 23rd Ave.
13. 2316 Cropsey Ave.
14. 275 Bay 37th St.
15. 2121 Shore Pkwy.
16. Waldbaum's
17. Brooklyn School for Special Children.
18. Bus Garage

1" = 1,000' (approximate)

FIGURE 5-2 MAJOR & INTERMEDIATE ENERGY CONSUMERS

Regina Pacis Residences

Location: 2424 Cropsey Avenue
Map reference No.: 2
No. residents: 330
Type fuel: Interruptible gas
Type heating system: Steam
Annual heating requirement (million Btu): 10,100

JHS 281

Location: Bay 37th Street and Harway Avenue
Map reference No.: 3
No. students: 1,700
Type fuel: Oil
Type heating system: Steam
Annual heating requirement (million Btu): 15,400

Sephardic Home for the Aged

Location: 2266 Cropsey Avenue
Map reference No.: 4
No. residents: 176
Type fuel: Interruptible gas
Type heating system: Steam
Annual heating requirement (million Btu): 24,400

Lawson Life Extension Institute

Location: 2300 Cropsey Avenue
Map reference No.: 5
No. residents: 245
Type fuel: Oil
Type heating system: Hot water
Annual heating requirement (million Btu): 11,200

Korvette's (temporarily occupied by a flea market)

Location: Bay Parkway Shopping Center
Map reference No.: 6
No. residents: N/A
Type fuel: Gas
Type heating system: Hot air
Annual heating requirement (million Btu): 11,000

Sanitation Garage (proposed)

Location: Bay 41st and Shore Parkway
Map reference No.: 7
No. residents: N/A
Type fuel: To be determined
Type heating system: Hot water
Annual heating requirement (million Btu): 18,000

Bus Garage

Location: 25th Avenue and Harway Avenue
Map reference No.: 18
No. residents: N/A
Type fuel: N/A
Type heating system: N/A
Annual heating requirement (million Btu): 20,000

Fountainbleu Apartments

Location: 8855 Bay Parkway
Map reference No.: 8
No. residents: 380
Type fuel: Interruptible gas
Type heating system: Steam
Annual heating requirement (million Btu): 13,100

Oxford Apartments

Location: 188 Bay 38th Street
Map reference No.: 10
No. residents: 350
Type fuel: Oil
Type heating system: Steam
Annual heating requirement (million Btu): 11,200

5.2.2 Intermediate Consumers

Several smaller establishments with annual heat consumption between 800-10,000 million Btu/year are listed in Table 5-3 and located on Figure 5-2. In most cases, heating requirements have been estimated using information supplied by Brooklyn Union Gas and local fuel oil suppliers. The total annual heating requirement for this subgroup is 46,180 million Btu, or 9 percent of the total area heating requirement.

Table 5-3

Intermediate Energy Consumers in Study Area

Consumer		Annual Heating Requirements million Btu
Multifamily Apartments		
2213 Cropsey Avenue	(36 units)	2,880
8835 23rd Avenue	(30 units)	2,400
275 Bay 37th Street	(78 units)	6,240
2316 Cropsey Avenue	(22 units)	1,760
2121 Shore Parkway	(105 units)	8,400
Commercial and Institutional Establishments		
Brooklyn School for Special Children		8,500
Waldbaum's		8,500
Bayview Manor		7,500
Total		46,180

Table 5-4

Heating Requirements of Private Residences in Study Area

Residence	Annual Heating Requirement million Btu	No. of Units	Annual Total Heating Requirement million Btu
One family	129	350	45,150
Two family	150	660	99,000
Three-five family	400	200	80,000
Six-15 family	800	30	24,000
Total		1,240	248,150

5.2.3 Private Residences

Private residences were grouped to include residential buildings containing less than 16 apartments with an annual heating requirement less than 800 million Btu per building. One- and two-family residences comprise 81 percent of this group; three- to five-family buildings comprise 17 percent. A more complete breakdown is presented in Table 5-4. From information supplied by Brooklyn Union Gas, it was estimated that over 90 percent of these residences utilize steam heating systems. These figures were confirmed in conversations held with local suppliers of residential fuel oil and local real estate brokers. Gas is the predominant fuel source in this area, used by over 60 percent of the private residences. The remainder can be assumed to be oil-heated since electric space heating in residential buildings is practically nonexistent in this area. The total heating requirement estimated for this group of private residences (1,240 units) is 248,150 million Btu/year, or 50 percent of the study area heat load.

5.2.4 Future Development

At the time this study was performed, a large new car dealership was under construction on Shore Parkway, east of the incinerator. Plans for the adjacent vacant lands include the construction of a racketball facility, and the previously mentioned Sanitation Department garage.

Dreier-Offerman Park lies on the southern boundary of the study area. At the present time, this area is undeveloped and no plans for improvement are pending with the Community Board.

5.3 DISTRICT HEATING SYSTEM

District heating is a proven technology for supplying space and hot water heating requirements using a thermal energy network. Steam or hot water produced in one or more central generating stations is used to supply a portion of, or the entire heating energy requirements of residential, commercial, and industrial buildings within a specific area.

Although systems of this type have been used in the United States since the late 19th century, inexpensive and seemingly "infinite" supplies of energy prevented their full development. Recent fluctuations in the price and availability of fossil fuels have caused a resurgence in development of alternative energy systems.

Over 300 district heating and cooling projects are in various stages of development in the United States. In contrast, the U.S.S.R. has approximately 70 times the installed capacity of the U.S. Modern, large-scale district heating systems are a major part of the national energy plans of Denmark, Sweden, France, and West Germany.

In order to evaluate the economic feasibility of installing a district heating system in the study area, two alternatives were developed. The first alternative, or full steam loop, utilizes a series of steam headers and laterals installed in the residential area directly across the Belt Parkway from the incinerator to supply steam to virtually all users within a three-quarter mile radius of the incinerator. The second alternative, or partial steam loop, utilizes a steam header connected to major energy consumers located on or adjacent to Cropsey Avenue. Both systems include condensate return lines.

Heat generated by the combustion of refuse in the furnaces will be converted to process steam by a series of waste heat boilers. Depending on the heating demand, this steam will be used to generate electricity or passed through an evaporator to generate steam for distribution to the heating system.

5.3.1 Load Duration Models

National Oceanic and Atmospheric Administration (NOAA) weather data for 1980 were analyzed to determine the length of the heating season and the ratio of peak/average heating loads. These data were provided so that the feasibility of steam extraction from the turbine and transmission requirements could be evaluated under steam demand conditions.

The number of heating degree-days in 1980 (based on 65°F) was within 5 percent of the average value reported in the ASHRAE guide, making 1980 a representative year. This analysis resulted in a total heating season of 5,600 hours, with a peak-to-average ratio of 2.76. Total energy demand for 1980 was averaged over the entire heating season to obtain the levelized flow rate. The remainder of the duration curve was synthesized using a cumulative frequency analysis of degree-days in 1980. A histogram of these data is presented on Figure 5-3.

Load duration models for each of the two alternative district heating systems presented on Figures 5-5 and 5-7, respectively, were developed using the degree-day histogram (Figure 5-3) to correspond to the actual connected load. The average hourly

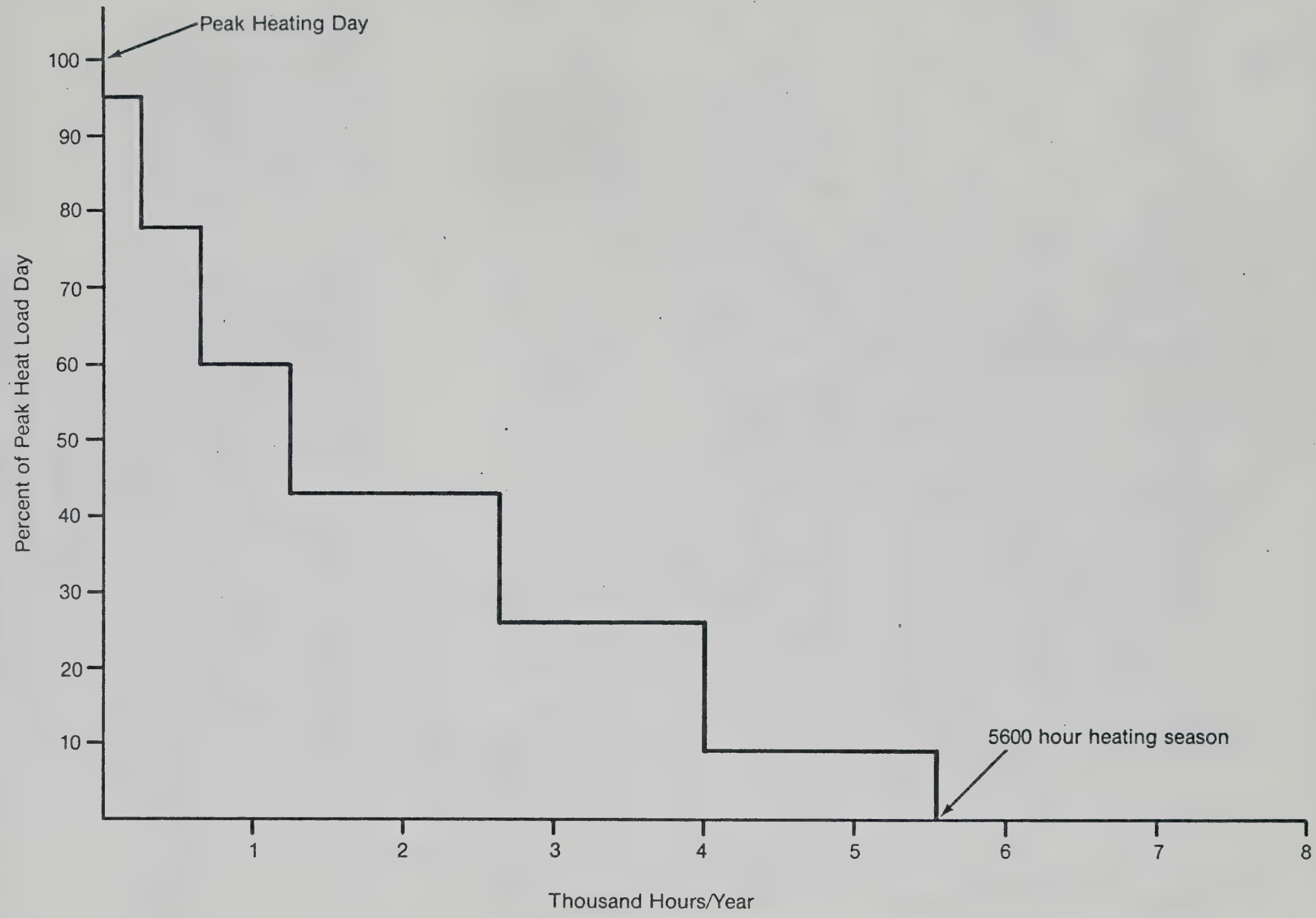


FIGURE 5-3 FREQUENCY HISTOGRAM
1980 HEATING SEASON

flow rate for each alternative was multiplied by 2.76 to obtain the peak value; the remaining points on the curve were computed using the proportions developed in the degree-day histogram.

5.3.2 Full Steam Loop

The portion of the study area incorporated into this alternative is illustrated on Figure 5-4. This layout provides heat for all major energy consumers in the study area, with the exception of the Korvettes' shopping center. Although this center lies approximately 2,500 feet from the incinerator, it was not included due to its relatively low population density and the incompatibility of its existing direct-gas heating equipment with utility steam.

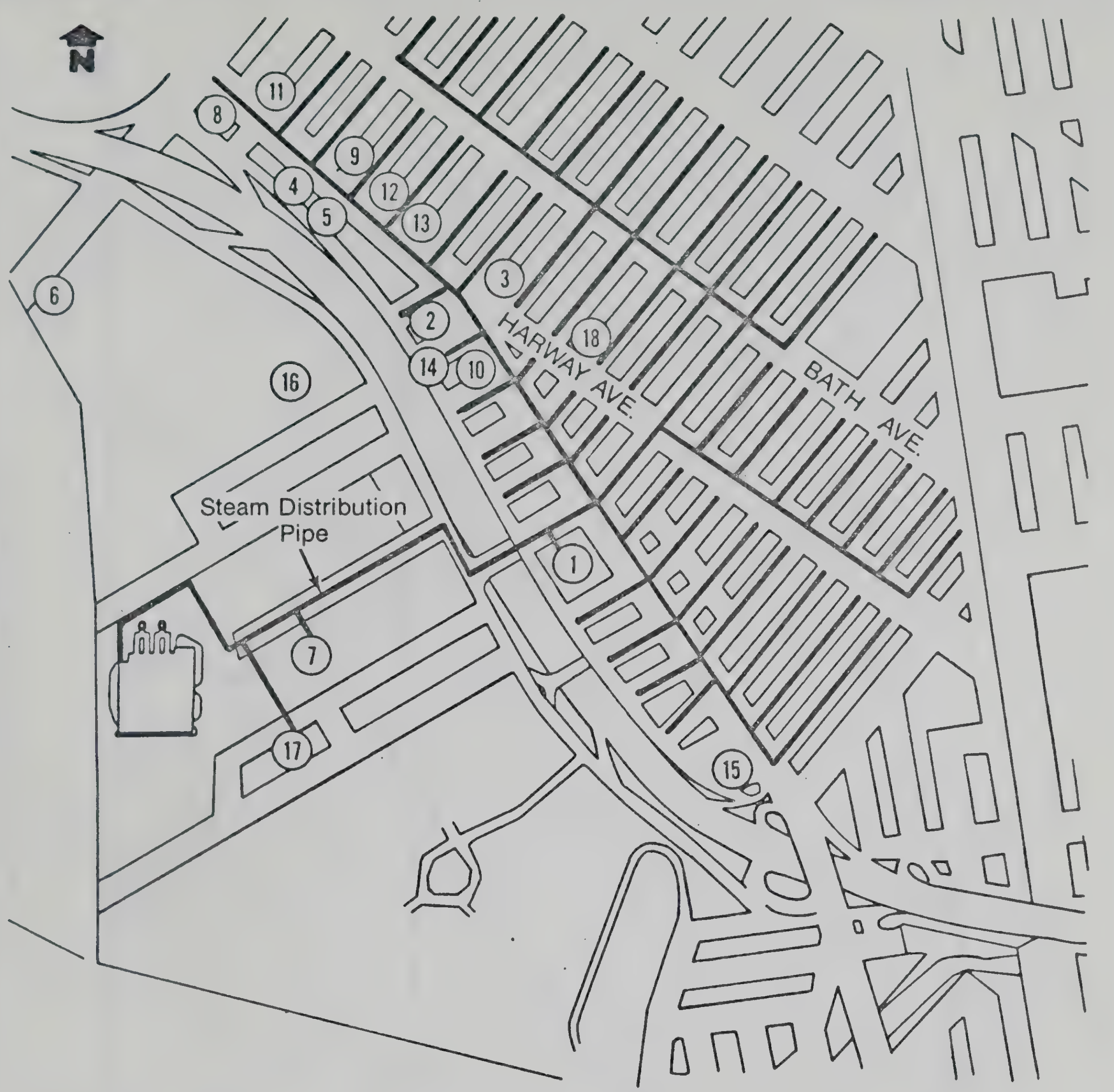
As proposed, this system incorporates nine of the major energy consumers listed in Table 5-2, seven of the multifamily apartments listed in Table 5-3, and approximately 1,200 private residences. Total average heat consumption for this layout is approximately 83,000 pph of steam (83 million Btuh), based on a 5,600 hour/year heating season. The load duration model for this alternative is illustrated on Figure 5-5.

Under actual operating conditions, the relative magnitude of the peak load may be substantially reduced since it is unlikely that all heating equipment will be in use at the same time. Empirically, this peak will be reduced by 20 - 25 percent(7); however, due to the possibility of industrial expansion in the adjacent area, no reduction was made on the peak demand for this alternative.

5.3.3 Partial Steam Loop

As may be seen on Figure 5-1, almost all of the major energy consumers lie on or adjacent to Cropsey Avenue. This alternative, as illustrated on Figure 5-6, was prepared to evaluate the economic feasibility of supplying energy to a select area.

The load duration model for this alternative is presented on Figure 5-7. Average steam demand for this alternative is 34,800 pph (34.8 million Btu/hr). System head losses require a minimum generating pressure of 53 psig at the plant. As mentioned previously, due to the relative ease of expansion, no peak reduction factor was applied to the load model.



1. Contello Towers
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12. 8835 23rd Ave.
13. 2316 Cropsey Ave.
14. 275 Bay 37th St.
15. 2121 Shore Pkwy.
16. Waldbaum's
17. Brooklyn School for Special Child.
18. Bus Garage

1" = 1000' (approximate)

FIGURE 5-4 FULL STEAM LOOP

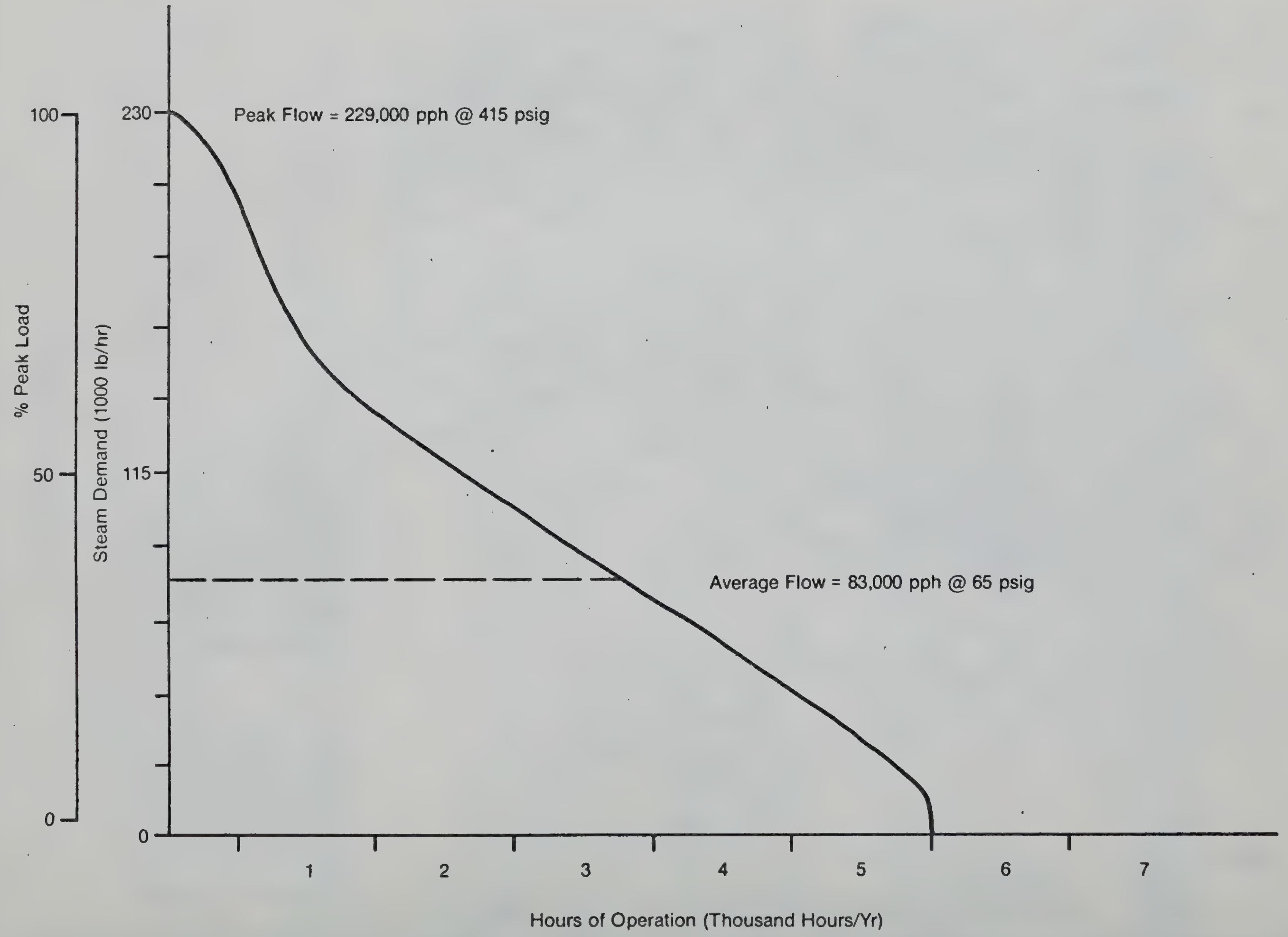
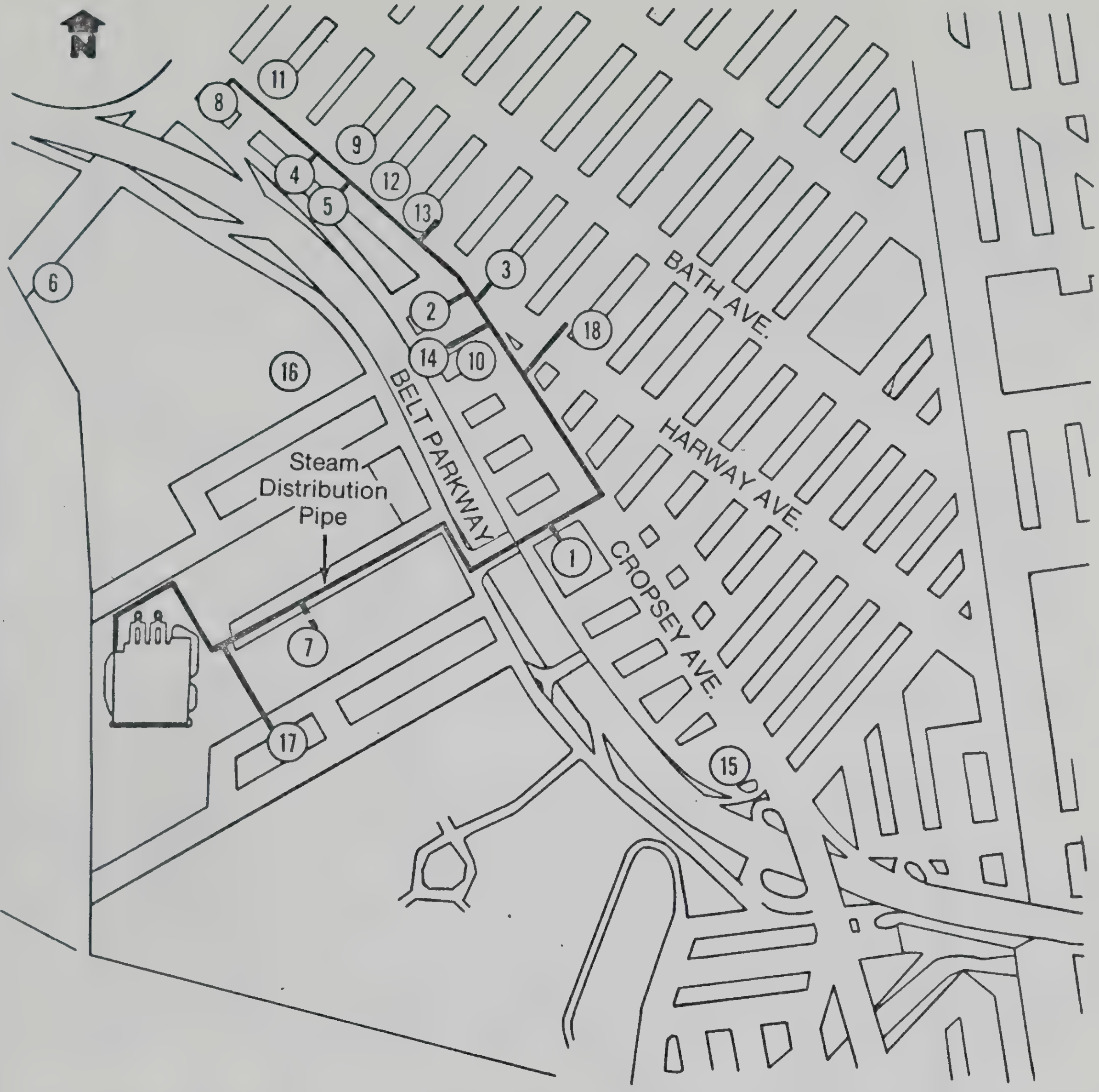


FIGURE 5-5 LOAD DURATION CURVE, DISTRICT HEATING SYSTEM— FULL STEAM LOOP



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17. Brooklyn School for Special Children.
18. Bus Garage

1" = 1000' (approximate)

FIGURE 5-6 PARTIAL STEAM LOOP

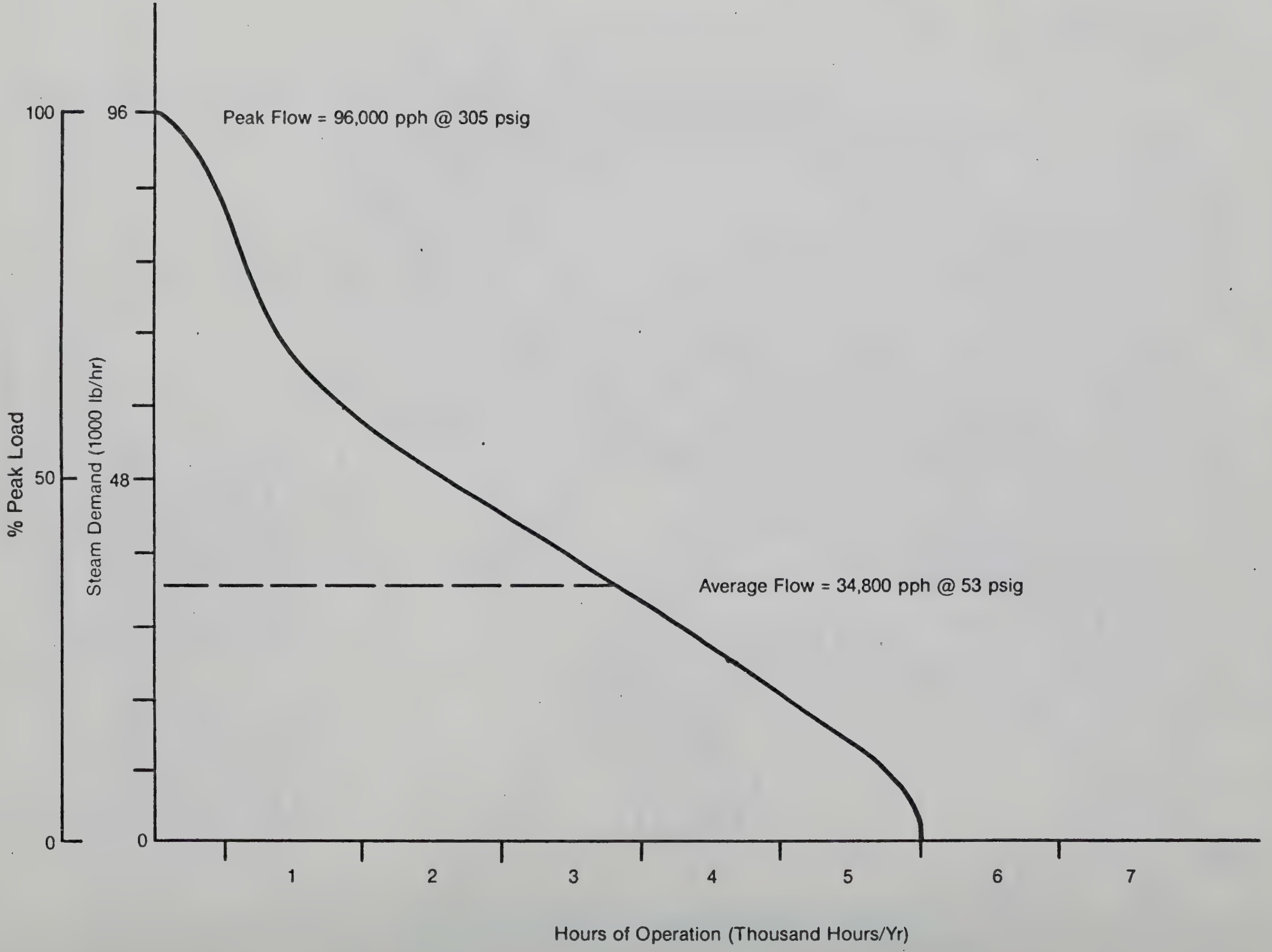

FIGURE 5-7 LOAD DURATION CURVE, DISTRICT HEATING SYSTEM—PARTIAL STEAM LOOP

5.4 CAPITAL COST ESTIMATES

Capital cost estimates for both district heating alternatives are presented in Tables 5-5 and 5-6. The costs presented for district heating only include transmission and distribution costs; those costs associated with the generation of steam and transfer to the distribution system are presented in Sections 6 and 7. Detailed descriptions of the major components are presented in the following subsections. The costs presented assume that steam can be supplied to the users without any significant modifications within the building.

5.4.1 Steam Header and Condensate Return

For both alternatives, the steam supply and condensate return piping will be carbon steel pipe conforming to ASTM A53 grade A or B. For the full steam loop, the supply header and condensate return pipes were assumed to be 14-inch and 8-inch diameter, respectively. The partial steam loop design assumed 10-inch and 4-inch diameter carbon steel piping, as above, for the supply and condensate return lines, respectively. Both pipes will be covered with 3 inches of mineral wool insulation to minimize transmission losses.

Access manholes with isolation valves will be provided at 400-foot intervals in the distribution system. Expansion joints will be fitted at each manhole to relieve stress caused by thermal expansion and settlement of the transmission and return lines. Inspection wells will be furnished at 200-foot intervals along the supply main in order to maintain the dirt legs and condensate collection equipment installed at these points. This equipment will include strainers, steam traps, and all associated fittings. Condensate collected in these traps will be discharged to the condensate return lines.

All connections in the piping system will be made using carbon steel butt welds. Nondestructive random radiographic inspection techniques will be employed to ensure the integrity of the connections.

Both supply and return lines will be installed in a common trench, using left-in-place sheeting as per New York City specifications. Cathodic protection devices will be installed in the trench to retard corrosion of the supply and return piping. Select backfill and pavement/roadway restoration will also be provided.

Table 5-5

Capital Cost Estimate -- Partial Steam Loop

Item	Cost
Steam header and condensate return piping	$3,613,000
Branch laterals to major and intermediate consumers	1,100,000
Hookups	
Major consumers	50,000
Intermediate consumers	12,000
Energy flow meters	
Major consumers	35,000
Intermediate consumers	12,000
Total	$4,822,000

Table 5-6

Capital Cost Estimate -- Full Steam Loop

Item	Cost
Steam header and condensate return piping	$ 9,013,000
Branch laterals to major and intermediate consumers	7,854,000
Private residence supply and return piping	3,933,000
Hookups	
Major consumers	70,000
Intermediate consumers	90,000
Private residences	968,000
Energy flow meters	
Major consumers	49,000
Intermediate consumers	90,000
Private residences	3,388,000
Total	$25,455,000

5.4.2 Branch Laterals

Branch laterals to major and intermediate consumers were assumed to be 4-inch diameter supply and 1 1/2-inch diameter condensate return lines for cost estimating purposes. Actual branch piping requirements will be developed in the detailed design of the distribution system.

Line items in the cost estimates for branch laterals include materials, excavation and sheeting, installation labor, fittings, and pavement restoration.

5.4.3 Private Residences Supply Piping

Supply and return lines for private residences were assumed to be 2-inch and 3/4-inch diameter, respectively. Line items for this supply piping include materials, excavation, installation labor, fittings, and pavement restoration.

5.4.4 Hookups

Individual consumer hookups were divided into categories based on consumer usage. Hookups for major, intermediate, and private consumers were developed from conversations with steam boiler manufacturers. Line items for each of these categories include thermostatically-controlled solenoid valves, pressure reduction valves, foundation penetrations, and installation.

5.4.5 Energy Flow Meters

For cost estimating purposes, energy meters of the electronic integrating type with dc battery back-up were used. Major consumers, such as high-rise apartments, were estimated using one central meter for the entire system. Individual apartments could be fitted with evaporative meters to provide equitable allotment of heating costs.

SECTION 6

WASTE HEAT BOILER AND TURBINE CONCEPT AND COSTS

6.1 INTRODUCTION

This section discusses the waste heat boilers, turbine generator, and balance of the plant equipment used to estimate the performance and costs associated with the proposed incinerator modifications. This section also contains an assessment of the condition of the existing incinerator, a discussion of potential boiler corrosion problems during energy recovery operations, and the influence of corrosion concerns on design parameters and configurations. Since numerous plant arrangements and configurations are possible, this section also addresses the philosophy behind equipment selections and arrangements. The basic philosophy used to select equipment arrangements was to maximize the reliability of the plant at a reasonable cost.

As previously presented, two alternative refuse-to-energy concepts were selected for evaluation in this scope of work:

1. Production of electricity.
2. Cogeneration of electricity and steam for distribution in a district heating system.

Both of these concepts incorporate mass-burning of "as received" refuse. No pretreatment such as classification or shredding will be incorporated into the selected alternative. The residue-handling equipment will remain essentially unchanged by the addition of any waste heat recovery equipment. The present air pollution control equipment will be modified with the installation of breeching and dampers to accommodate the installation of the boilers in the flue gas stream.

6.2 ASSESSMENT OF SOUTHWEST BROOKLYN INCINERATOR CONDITION

The feasibility of retrofitting an existing facility to recover waste heat is, for the most part, dependent on the condition of the existing installation. A facility in poor condition would require increased capital expenditures to upgrade it to a condition that would not constrain the energy recovery operation and increase its operating costs. A tour of the Southwest Brooklyn Incinerator was undertaken(24) to assess its overall condition and to outline requirements that could affect energy recovery.

The examination was undertaken by dividing the facility into major equipment items and major construction items, as follows:

1. Major Equipment Items.
    - a. Scales.
    - b. Cranes.
    - c. Furnaces.
    - d. Fans.
    - e. Air pollution control.
    - f. Residue removal system.
    - g. Instrumentation.
    - h. Flues and ductwork.
2. Major Construction Items.
    - a. Building.
    - b. Tipping area.
    - c. Storage pit.
    - d. Refuse hoppers.
    - e. Offices.
    - f. Employee facilities.
    - g. Stacks.

The results of this survey are presented in Table 6-1. This table highlights both the condition of the equipment and the status of corrective action being undertaken, if any, along with required activities as they relate to energy recovery.

In summary, except for some present difficulties with the new air pollution control equipment and excessive infiltration, the facility is in good condition. It is assumed in the remainder of the report that all ongoing activities will be completed by the City. Only renovations directly related to implementing energy recovery are addressed.

6.3 CORROSION CONCERNS

The degree of corrosivity of gases generated during the combustion of municipal refuse raises issues which affect numerous considerations. These include the following:

1. Temperature of the flue gases entering and exiting the waste heat boiler.

2. Steam temperature and pressure conditions.

Table 6-1

Existing Incinerator Status and Requirements

Item	Status/Condition	Required Activities
1. Major Equipment Items		
a. Scales	City in process of renovating and enlarging scale size	None
b. Cranes	Two overhead cranes -- good condition.	None
c. Furnaces	Furnaces and grates were installed in 1976 and are in good condition. Recent ORSAT tests indicate infiltration in the expansion chamber. Visual survey revealed potential leakage where the ductwork enters the furnaces. Significant heat loss is evident through the top of the furnaces where recorded ambient air temperature is well over 100°F. The City is presently evaluating all leaks to reduce induced draft fan power requirements.	Seal primary chamber leaks in ductwork, and insulate tops of furnaces to minimize heat losses.
d. Fans	Existing fans are in good condition.	Fans will be replaced or modified to accommodate waste heat boiler and air preheater requirements, included in subsection 6.5.5.

Table 6-1
(continued)

Item	Status/Condition	Required Activities
e. APC	The City is presently testing air pollution control equipment in order to start up operation. Difficulties have been encountered, which include clogging of gas conditioning tower spray nozzles and inadequate tower insulation. The City is presently trying to isolate the cause of the problem and negotiating with responsible contractors.	Potential problem with the air pollution control equipment will have to be reevaluated with respect to its effect on this project after the City completes its analysis.
f. Residue removal	Conveyors, flights, and chains in good condition.	None
g. Instrumentation	Forced air fan flow measurements are unreliable; adequacy in number and location of temperature probes for monitoring the furnace temperature profile is questionable.	The existing instrumentation is inadequate for the purposes of the new facility, and will have to be replaced; see subsection 6.5.7.
h. Flue and duct equipment	The air pollution control train is new -- installed in 1977 in forced air fan system. Guillotine dampers are a major source of leaks which the City is investigating to reduce induced draft fan power requirements.	Seal leaks in system; new design will require rerouting and some new duct work; see subsection 6.5.1.

Table 6-1
(continued)

Item	Status/Condition	Required Activities
2. Major Construction Items		
a. Building	Sound condition.	Will require structural modification; see subsection 6.5.9.
b. Tipping	Good condition, adequate space for 4-6 dumping spots; adequate for 1,000-tpd operation.	None
c. Storage	Good condition, adequate for 2-3 days of storage.	None
d. Refuse hoppers	Good condition.	None
e. Offices	Office space is available.	Will require appropriate partitioning for operating components.
f. Employee facilities	Present incinerator payroll staff is 78. Staff has ranged from 78-95; 115 lockers are available.	Presently adequate for 30-40 more personnel.
g. Stack	Minor structural damage in one stack, presently being planned for repair by the City.	None, given stack repair.

3. Boiler configuration, operation, and construction materials.

Design considerations such as flue gas and steam temperatures are addressed in detail in this subsection. Other considerations such as boiler configuration and materials of construction are addressed briefly but warrant more detailed evaluation during the engineering design.

Previous studies (25, 26) have examined corrosive constituents in municipal refuse incinerators, and the combined corrosive effects (27) of these constituents under the temperature ranges that are encountered in conventional municipal incinerators and municipal incinerators that utilize waste heat boilers.

Severe corrosive conditions result from the presence of chlorides and sulfur-bearing metallic salts in scale deposits that form on metallic surfaces. Chloride salts are generated via hydrogen chloride in the combustion of chlorinated plastics (PVC), and are also volatilized directly from chloride salts during the combustion process. Sulfur, which is normally found in refuse (0.1 - 0.15 percent by weight), reacts with oxygen and ash minerals to produce sulfates. Ferric chloride ($FeCl_2$), potassium pyrosulfate ($K_2S_2O_7$), potassium bisulfate ($KHSO_4$), as well as lead (Pb) and zinc (Zn) chloride and sulfate salts detected on metal surfaces are believed responsible for much of the identified corrosion. The presence of lead and zinc chloride and sulfate salts aggravate the problem because of the low melting points of these salts which enhance galvanic corrosive activity.

Metallic corrosion in municipal incinerators with convection or waterwall boilers has been shown to be temperature dependent.(27) In general, the corrosivity of the metallic salts generated increases rapidly at metal tube temperatures greater than 600°F. The most corrosive salts at 600°F are the bisulfates and pyrosulfates. Chloride corrosion increases rapidly at temperatures greater than 800°F. Municipal refuse incinerators generating steam have experienced less boiler tube corrosion when generating low pressure and temperature steam (300°-400°F), with low waste heat gas temperatures than those generating superheated steam.

In addition to corrosion resulting from chloride and sulfur-bearing salt compounds, condensation of corrosive sulfur and chloride gases (dew point corrosion) can result in the formation of sulfuric acid (H_2SO_4) and hydrochloric acid (HCl) at their respective dew points (approximately 300°F and 225°F, respectively). Corrosion can also result from hydrogen sulfide (H_2S) and carbon monoxide (CO) gases, produced by incomplete combustion, which attack the iron oxide or protective coating of metal tube surfaces.

Dew point corrosion of waste heat boiler tube surfaces can be prevented by maintaining an adequate temperature throughout the flue gas flow scheme. Reducing atmospheres can be prevented by supplying a proper fuel-to-air ratio that provides sufficient oxygen for complete combustion. Adequate turbulence will prevent the formation of dead spots where a reducing atmosphere can form. Mitigating measures for chloride and sulfur-bearing salt corrosion warrant design and operating conditions that minimize slag formation on the boiler tubes and maintain metal tube temperatures as low as possible.

A survey of European and United States boiler vendors was undertaken to review their suggestions concerning design and operating steam temperatures and pressures for superheated steam generation in municipal refuse combustion applications. The results of this survey are presented in Table 6-2.

Every vendor expressed some degree of concern with respect to corrosion with superheated steam generation, and each offered comments with respect to minimizing its impact. One of the more notable differences was the recommended waste gas temperature, between 1,400°F and 1,200°F. The lower 1,200°F temperature was recommended to reduce slagging on the boiler tubes and prevent the corrosive salt buildup.

Field visits to three installations (see trip reports, Appendix L) with convection tube waste heat recovery applications were also undertaken to review potential operating problems. In general, the field visits yielded the following:

1. Supplemented existing data relative to concern regarding the severity of chloride corrosion (see Phelps-Dodge trip report, Appendix L).

2. Verified waste heat recovery feasibility at high temperature waste gas applications (see Chevron trip report, Appendix L).

3. Illustrated waste heat recovery applications utilizing municipal refuse with the recycling of spent boiler gases to attemperate the waste heat gas temperature.

Table 6-2

Recommended Design Parameters for Generation of Superheated Steam

Vendor	Boiler Gas Inlet Temp. °F	Steam Pressure Temperature psig	Steam Pressure Temperature °F	Feed-water Temp. °F	Other Comments
Deltak	1,400	600 450 250	750 600 500	320	Concern with high degree of superheat; prefer lower superheated temperature conditions. Double-walled tubing available to prolong life of tubes.
Zurn	1,400	650	700	280-300	Not as concerned as Deltak, but high degree of superheat could cause problems. Silicon carbide protection available for boiler tubes.
Bigelow	1,400	650	700	---	Concern over superheated corrosion of screen tubes, sacrificial superheater tubes are available that can be easily replaced. Split superheater available with first stage made of special alloy and second stage of carbon steel placed back into boiler.
Enotherm	1,200	250-450	650-700	---	Corrosion not major problem with steam temperature less than 750°F.
Volund	1,200	650	650-700	280	1,200°F maximum waste gas temperature to prevent slagging in convection section.
Katy-Seghers	1,200	600	600	284	Attemperator available in convective superheater section to control superheater temperature.

4. Illustrated the use of wall cooling air for underfire preheating (see Pittsfield trip report, Appendix L).

It is apparent from the literature, vendor surveys, and field trips that the effects of corrosion cannot be completely eliminated and the goal of the design should be to minimize the severity of corrosion by proper operating techniques, temperature control, and metallurgical considerations in the selection of boiler materials.

6.4 OPERATIONAL DESIGN CONSIDERATIONS

On the basis of the previous review outlined in subsection 6.3, recommended operating parameters for the waste heat boiler design are as follows:

Waste gas waste heat boiler inlet temperature	1,200°F
Steam pressure	650 psig
Steam temperature	750°F
Feedwater temperature	280°F

The waste gas temperature will be reduced from 1,400°F in the secondary chamber to 1,200°F by recycling approximately 11,400 SCFM of 450°F exit gases from the boiler, and bleeding ambient air back into the ductwork between the secondary chamber and boiler inlet, as required (see Figure 6-4). This is designed to reduce and/or eliminate the builduip of slag on the boiler tubes, and to provide operational control over waste gas temperature. More detailed design considerations will be required to assess material requirements, attemperating superheaters, sacrificial superheater tubes, and double-walled tubing proposed by various vendors in the engineering design (see Section 10).

For the purposes of this study, it has been assumed that the boiler internals will have a service life of 12.5 years.

6.5 ELECTRICITY ONLY -- CONCEPT AND COSTS

In this alternative, the entire steam output of the waste heat boilers will be used in the generation of electricity for distribution to Consolidated Edison's nearest substation. A simplified flow diagram of the electricity generation system is illustrated on Figure 6-1. A general equipment layout is presented on Figure 6-2. Descriptions of the following major components of this system are presented:

1. Waste heat boilers.

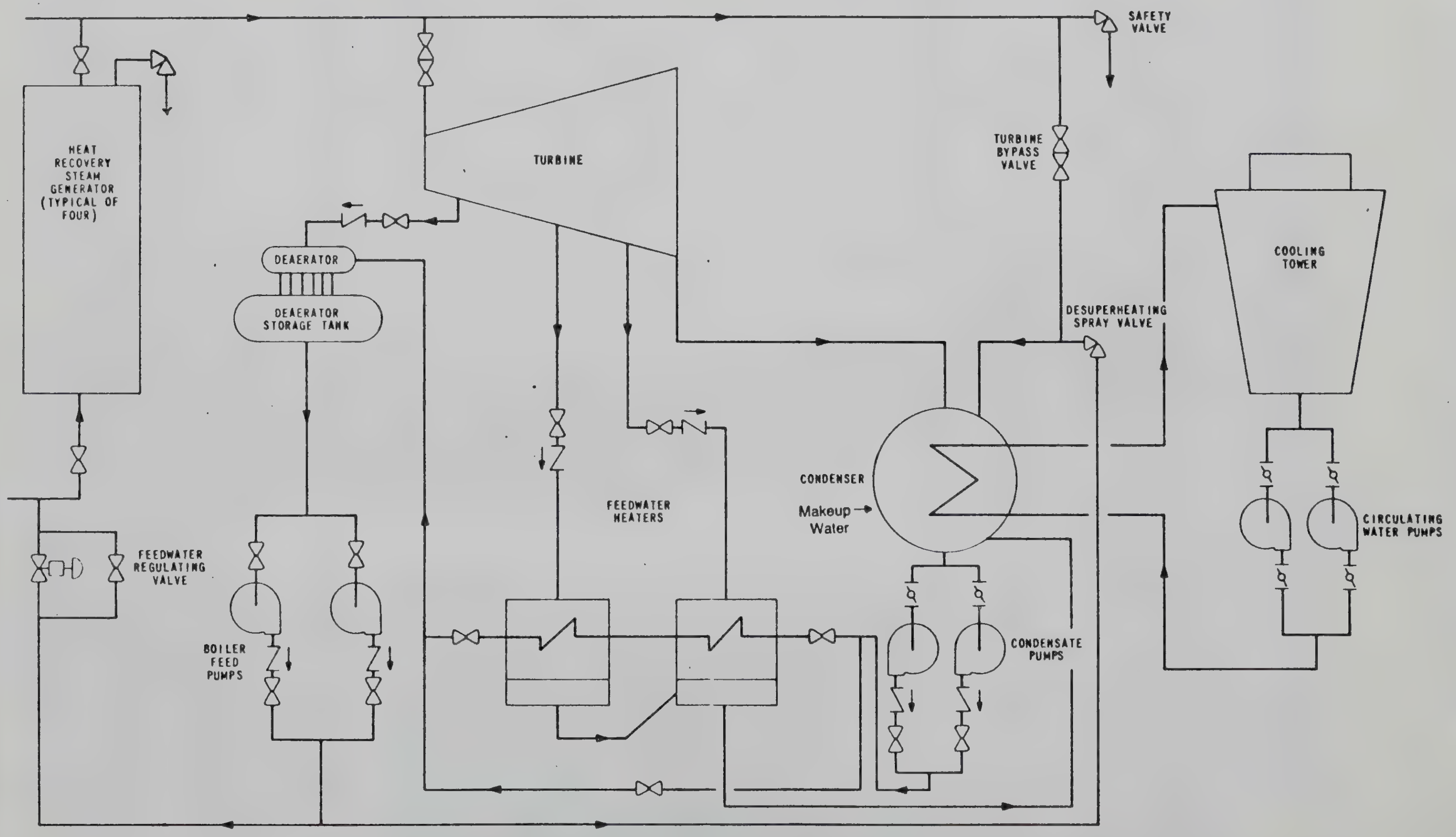

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FIGURE 6-1 SIMPLIFIED FLOW DIAGRAM—ELECTRICITY GENERATION SYSTEM

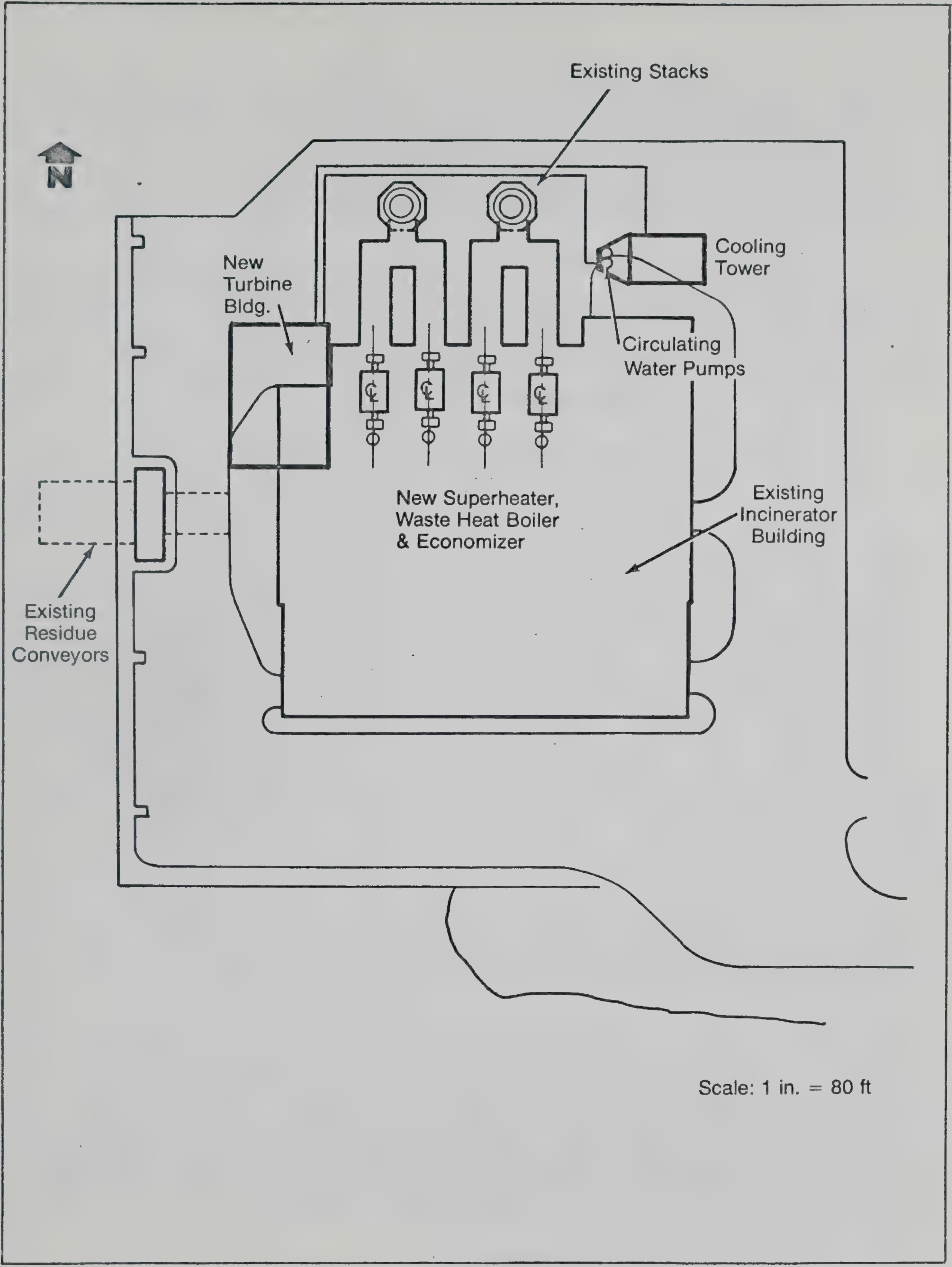
Existing Stacks
N
Cooling Tower
New Turbine Bldg.
Circulating Water Pumps
New Superheater, Waste Heat Boiler & Economizer
Existing Incinerator Building
Existing Residue Conveyors
Scale: 1 in. = 80 ft

FIGURE 6-2 EQUIPMENT LAYOUT

2. Turbine generator.
3. Feedwater cycle.
4. Heat rejection equipment.
5. Auxiliary equipment.
6. Water treatment equipment.
7. Controls and instrumentation.
8. Electrical equipment.
9. Structural requirements.
10. Fly ash conveying system.

6.5.1 Waste Heat Boilers

Flue gases produced by the combustion of refuse in the furnace will be conveyed from the existing secondary chamber to the waste heat boilers by a new vertical breeching connection located in the drop-out section immediately beyond the exterior incinerator building wall. A boiler gas recirculation system will utilize exit gases (at 450°F) to attemporate the 1,400°F flue gases. Flue gas will enter the boilers at approximately 1,200°F and exit at 450°F, generating approximately 45,500 pph of superheated steam (700°F, 650 psig) per furnace. Each of the four furnaces will be equipped with an identical waste heat boiler.

The four boilers will be of the bare water tube type with carbon steel jackets specifically designed for "dirty" flue gas applications. The boilers will be furnished with a replaceable economizer and superheater section, fly ash hoppers, mud drums, insulation, pneumatic soot blowers, and boiler trim.

Each boiler will be of steel shell construction, insulated and aluminum-jacketed, approximately 12 feet wide, 16 feet high, and 45 feet long, including the economizer and superheater sections. Two fly ash removal hoppers will be furnished on each unit. The total weight of each boiler, including water, is approximately 320,000 pounds. Feedwater pumps will supply treated process water to the boilers. Steam produced in the boilers will be piped to the turbine; the condensate will be returned as part of the closed cycle.

Flue gases will be recirculated through a carbon-steel, externally-insulated duct back to the uptake flue to the boilers. Approximately 11,400 SCFM (at 450°F) will be recirculated. An induced-draft fan, powered by a 30-hp drive will be supplied to recirculate the gases. Provision will be made to introduce ambient air into the recirculation system to allow greater operational flexibility.

The cooled flue gases exiting from the waste heat boilers will be conveyed back to the existing gas-conditioning tower by new externally-insulated carbon steel breeching. Under normal operating conditions, the gas-conditioning tower will act as an extension of the exhaust breeching and serve to convey the cooled flue gases to the electrostatic precipitator.

In the event that the flue gas moisture content drops to the point of detrimentally affecting the particulate collection efficiency of the electrostatic precipitators, moisture can be addded to the flue gas by the spray nozzles to condition the gases. The resultant drop in flue gas temperature will be offset by the additional insulation thickness specified over the temperature differential allowed; the tower will also serve as an additional particulate drop-out section. Under boiler bypass conditions, (whenever the boiler exit temperature falls below 450°F), the hot flue gases will be diverted through the gas conditioning tower and the water sprays in the tower will be automatically activated to cool the flue gases prior to their introduction to the precipitator.

Insulation will be applied to the exterior of the gas-conditioning tower to minimize heat loss. In this manner, the amount of heat extracted in the waste heat boilers can be maximized without subjecting the precipitator internals to potential corrosion caused by low inlet gas temperatures.

The installation of the waste heat boilers and associated ductwork will require modification of the existing induced-draft fan and drive to overcome the additional system pressure drop reported in subsection 4.2.2.3.

6.5.2 Turbine Generator and Accessories

The basic turbine arrangement consists of one turbine generator which is supplied with steam from all or any combination of the waste heat boilers. Based on economy of scale estimates, this arrangement was chosen over other possible plans using multiple turbines. It is estimated that two half-capacity turbines of this size would cost approximately 30 to 35 percent more than one full-sized turbine and would increase the overall availability of the system by only a few percent.

The turbine generator is sized to operate with the design steam flow of 182,000 lbs/hr, which is the anticipated flow with all four waste heat boilers in operation.

In addition, the turbine generator manufacturers routinely include a 5 percent flow margin above the guaranteed steam flow. The turbine is expected to be capable of operation with flows up to 195,000 lbs/hr.

The turbine is sized so that its best efficiency point occurs at the steam flow corresponding to three out of the four boilers in service. Having the best efficiency point at that flow instead of the flow with four boilers in service is desirable since the plant will be operating 38 percent of the time with three boilers in service, and only 29 percent of the time with four boilers in service. Therefore, the turbine is expected to operate at its best efficiency point approximately 38 percentt of the time. The design approach used is to size the turbine for the best efficiency with three of the four incinerators operating since this is the most frequent operating point.

The turbine is a single flow 3,600 rpm, nonreheat, straight condensing steam turbine rated at 17,600 kW_e. The turbine is designed for a throttle flow of 185,000 lbs/hr of steam at 650 psig and 700°F, exhausting to a back pressure of 3.0-inches Hg absolute. The turbine includes three extractions for feedwater heating at 50 psia, 20 psia (approximate), and 7 psia (approximate). The design includes a turbine bypass system. This system increases the operational capability of the plant since steam can bypass the turbine and be routed directly to the condenser. The general arrangement is shown on Figure 6-1. Desuperheating spray would be taken from the boiler feed pump outlet and injected into the steam to prevent condenser damage from high temperature steam. The turbine bypass arrangement would allow incinerator operation following a turbine trip, and allows refuse incineration and steam generation whenever the turbine generator is out of service or during the startup mode.

The generator is rated at 20,700 kVA with a 0.85 power factor. The terminal voltage is 13,800 volts and 60 Hz, three-phase. The generator is hydrogen-cooled at 30 psi and is equipped with hydrogen coolers designed for 95°F cooling water. The exciter is a 250-volt, static excitation system complete with power transformer, current transformer, and excitation cubicle containing all the necessary equipment for remote control.

Turbine generator accessories include the following necessary items:

1. Stop valves.
2. Steam strainers.
3. Automatic steam inlet control valve gear.
4. Electrohydraulic control system.
5. Turbine generator lubricating oil reservoir and supply equipment, including motor- and steam turbine-driven emergency oil pumps.
6. Gland-sealing system, including vacuum pump.
7. Fabricated metal-lagging for high temperature parts of the turbine.
8. Extraction nonreturn valves.
9. Thermocouples and recorder for controlled starting and synchronization.
10. Supervisory instruments.
11. Generator temperature detectors.
12. Generator cooling system.
13. Hydrogen control system.
14. Sole plates.
15. Lifting slings and rotor skids.
16. Special installation and maintenance tools.
17. All other accessories and features as required for the complete unit.

6.5.3 Feedwater Cycle

The feedwater cycle consists of the condensate pumps, feedwater heaters, deaerator, waste heat boiler feed pumps, and associated piping and valves. The basic cycle heat balance is shown on Figure 6-3. The condensate pumps transport the condensed steam from the condenser hotwell through the feedwater heaters to the deaerator. The deaerator storage tank provides suction for the boiler feed pumps which pump the feedwater to the waste heat boilers. Based on the reliability estimates and size of the pumps, two full-capacity pumps are used. The net turbine heat rate for four-boiler operation with no district heating is 11,730 Btu/kWh. This includes 170 kW for boiler feed pump power, and is the standard definition of net turbine heat rate. Figure 6-3 is sketch of the proposed cycle arrangement, and therefore, is not meant to be a detailed piping and instrument diagram. Moisture separators are not required in the extraction lines since the steam is superheated. The extraction and steam lines would include nonreturn check valves, drip pots, drain and drip piping, and control instrumentation as required to prevent turbine water induction. These requirements would, of course, be addressed during detailed design.

The final feedwater temperature to the waste heat boiler is approximately 280°F. This temperature was selected as being representative of other similar installations, and is typical of turbine cycles in this size range. Higher feedwater temperatures, e.g., 350°F - 380°F, require more extraction steam, which must be extracted at a higher pressure from the turbine. This increased extraction reduces the amount of electricity that can be generated. Temperatures much below the feedwater temperature used could increase the potential for corrosion of the economizer tubes by sulfuric and hydrochloric acid attack due to tube temperatures below the condensation temperature of gaseous sulfuric aicd. The design parameters for the feedwater system are shown in Table 6-3.

Turbine manufacturers were contacted to determine the number of feedwater heater extractions that are feasible for a turbine of this size. The general conclusion is that three feedwater heater extractions[1] (two low-pressure heaters and a deaerator) are

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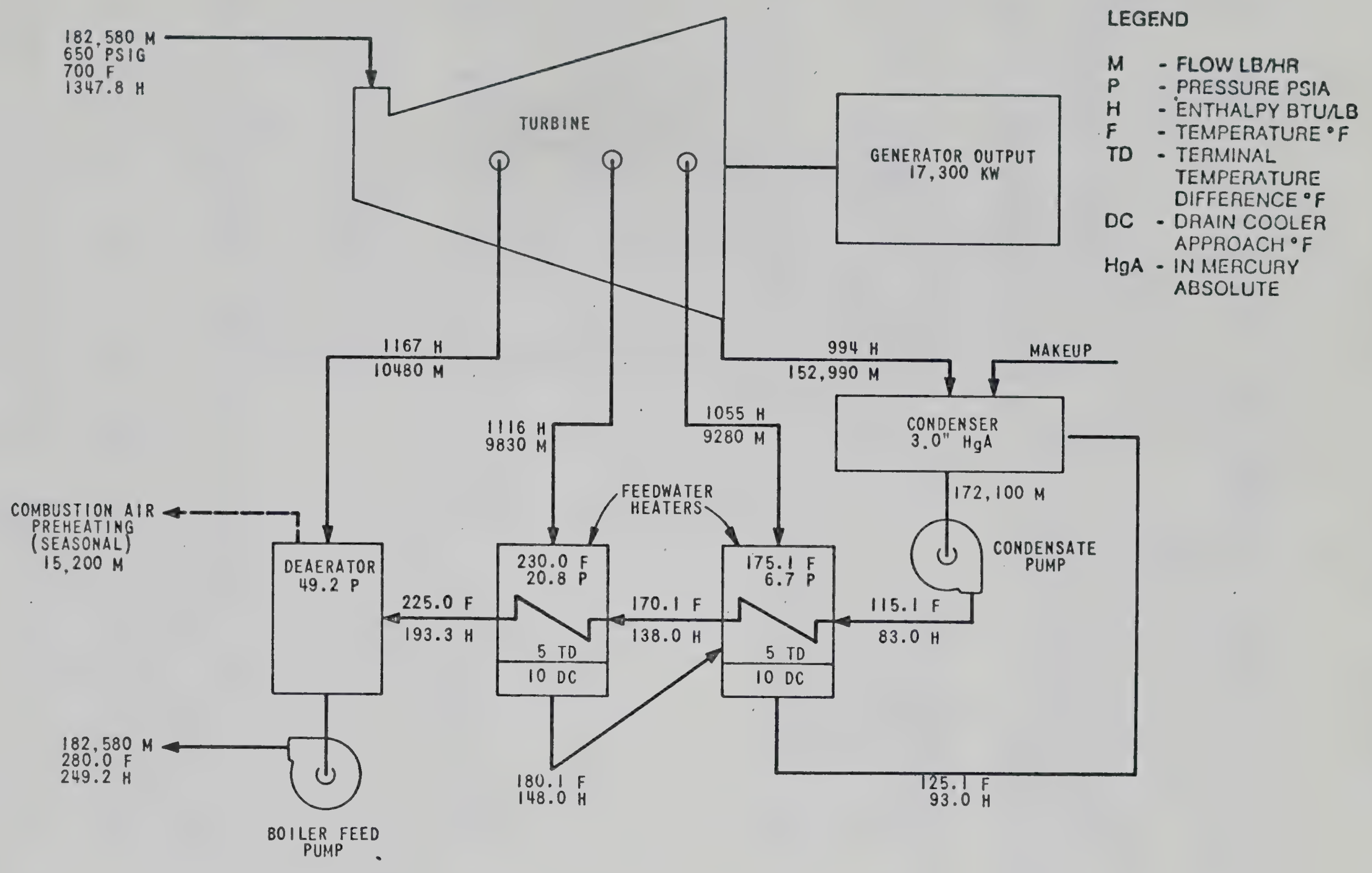
[1] The actual number of feedwater heaters can depend on the turbine manufacturer selected. This assumption should be reevaluated after a manufacturer has been selected during detailed design.



$$\text{NET TURBINE HEAT RATE} = \frac{182{,}580\ (1347.8 - 249.2)}{17{,}300 - 170} = 11{,}710\ \text{BTU/KW-HR}$$

FIGURE 6-3 FEEDWATER CYCLE HEAT BALANCE

Table 6-3

Preliminary Feedwater Cycle Design Parameters

Equipment	Design Parameters
Condensate pumps (two full-capacity pumps)	370-gpm flow, 180-foot total pumping head, with 30-hp, 1,760-rpm, 480-volt motor.
Boiler feed pumps (two full-capacity pumps)	420-gpm flow, 1,890-foot total pump head, with 250-hp, 3,600-rpm, 480-volt motor.
Low-pressure feedwater heaters	The heaters are horizontal with carbon steel shells and stainless steel tubes. Steam extraction conditions at full load are approximately 7 psia and 20 psia as shown on the heat balance. Feedwater flow and conditions are as shown on the heat balance. Heaters are sized for 5°F terminal temperature differences and an internal drain cooler with a 10°F approach.
Deaerator	The deaerator is a direct contact spray type. The vertical cylindrical heater section is supported on the horizontal storage tank. The design conditions are shown on the heat balance.

feasible for this cycle with a final feedwater temperature of about 280°F. Therefore, the feedwater heater cycle incorporated into the design includes two feedwater heaters and a deaerator.

The deaerator storage tank is sized for a 5-minute storage capacity to minimize the influence of transient conditions such as start-up and load changes. A single deaerator is included in the design. An additional deaerator can be included in the design, if desired, and the cost would not significantly impact the outcome of this feasibility study.

The boiler feed pumps are horizontal split-case types with diffuser vane construction and double suction impellers. Two full-capacity pumps are included in the preliminary design. The boiler feed pumps are suitable for low-flow operations with several incinerators/waste heat boilers out of service. Recirculation lines and valves are included in the design. The feed pump system includes coupling, motor drives, lube oil systems, and all other necessary accessories.

6.5.4 Heat Rejection Cycle

The heat rejection cycle system consists of the condenser, cooling tower, circulating cooling water piping, pumps, and motors. The basic design parameters of the system are listed in Table 6-4.

The cooling cycle is a recirculating type. The heated cooling water from the condenser flows over the cooling tower where the heat is rejected to the atmosphere. The cooled water is collected in the cooling tower basin and pumped back through the condenser. Blowdown is discharged through a 1-inch line to the existing sewer connection. Make-up water is obtained from the city water main and is piped through a 3-inch line to the pump pit.

The condenser is sized to provide a reasonable back pressure under all expected operating conditions. The design parameters are selected based on engineering judgment since there are many possible condenser design variables. The condenser is a two-pass design to provide a representative temperature rise for cooling tower operations. The tube length is 18 feet based on the expected turbine foundation size.

A separate cooling tower and surface condenser is used instead of air-cooled type condensers. Other refuse burning plants have

Table 6-4

Heat Rejection System Design Conditions

System	Design Condition
Condenser	
Number of passes	2
Tube length, ft	18
Material	304 SS
Velocity, ft/s	7.0
Back pressure, inches HgA, peak	4.5
Surface area, sq ft	9,100
Flow rate, gpm	14,700
Cooling Tower	
Wood, cross-flow type with dry-cooling section for plume abatement	67 ft wide x 61 ft long x 70 ft high
Design wet bulb temperature, °F	77
Approach, °F	12
Range, °F	19.0
Fan size, hp	200
Circulating Water System	
Pump capacity, gpm	15,500
Arrangement	Vertical, wet pit type
Total developed head, ft	70
Motor horsepower	400
Pipe material	Fiberglas reinforced pipe (FRP)
Pipe size, in.	24
Pipe velocity, ft/s	11.0

experienced considerable start-up delays and operational problems with air-cooled condenser designs. Air-cooled condensers normally produce higher back pressures than water-cooled condensers. The higher back pressure reduces the amount of energy that can be removed from the steam, thereby resulting in lower generation than with a water-cooled condenser and evaporative cooling tower. Air-cooled condensers are more expensive initially, consume more auxiliary power, and produce higher plant heat rates than water-cooled condensers; however, they make the plant easier to license and consume less water. Their use is normally limited to areas where water for tower makeup is extremely scarce or siting of a steam plant prohibits using an evaporative cooling tower. Air-cooled condensers should be considered during detailed design if the evaporative tower is expected to create an environmental concern.

The cooling tower is a wooden rectangular tower of the crossflow design. The tower would serve as a plume abatement tower to elimiate fogging and icing of the area around the plant. The plume abatement tower is a wet/dry cooling tower that uses a dry heat exchanger in addition to the conventional wet (evaporative) fill section. The amount of tower drift can be controlled by changing the proportion of the heat rejected in the wet and dry sections.

The cost of the plume abatement tower can vary significantly based on the size of the dry system selected. It is estimated that the capital cost of the plume abatement tower is about 2.5 times more than the conventional (wet) tower. The dry portion of the tower could be sized based on the specific ambient conditions at the plant during detailed design development. The operating costs of a plume abatement tower can be expected to be higher than those costs of an all wet system. Maintenance costs would be higher and the fan and pumping power requirements would be greater.

The total circulating cooling water flow rate is 15,500 gpm. This is composed of 14,700 gpm from the condenser and 800 gpm from the auxiliary heat exchanger. The supply and return piping to the condenser would be 24-inch reinforced fiberglas pipe. Two full-capacity circulating water pumps are planned. These pumps are vertical, wet pit pumps with a design condition of 15,500 gpm and a total developed head of 70 feet. The pump motors are rated at 400 horsepower. The circulating water cooling pump structure includes the pump pit, a building that covers the total pit area, the flume from the tower basin, and a crane to remove the pumps and motors.

6.5.5 Auxiliary Systems

This subsection discusses the auxiliary mechanical systems that are required. The systems are:

- Main steam.
- Extraction steam piping.
- Air preheaters.
- Auxiliary cooling.
- Make-up water.
- Compressed air.
- Lube oil conditioning.
- Condenser vacuum equipment.

1. Main Steam.

   The main steam piping system includes all of the piping, fittings, valves, hangers, and insulation from the waste heat boilers to the turbine. The piping would be routed from each waste heat boiler and connected into a common header to the turbine. The piping would be designed for the maximum expected flow conditions, including margins for pressure and temperature transients. The piping would be designed so that any number of waste heat boilers can be operated at one time.

2. Extraction Steam Piping.

   The extraction steam piping includes all fittings, valves, hangers, and insulation required to provide extraction steam from the turbine casing to the feedwater heaters and deaerator. The design conditions would be based on the extraction flows and pressures required. Stop valves, automatic condensate removal valves, and nonreturn valves would be provided for flow control and as required to prevent turbine water induction.

3. Air Preheaters.

Steam coil air preheaters will be installed in the underfire air system of each boiler. These heaters were found to be the most compact, effective method to preheat the underfire air. Since an air side pressure drop of approximately 4 in. H_2O is anticipated, larger underfire air fans will be installed on each furnace. Approximately 15,000 lbs/hr of steam would be extracted to preheat the underfire air from 70°F-250°F, whenever the inlet temperature of the boilers cannot be maintained at 1,200°F.

4. Auxiliary Cooling System.

For the feasibility study, it is assumed that a separate auxiliary cooling system is required to provide cooling water to all plant auxiliaries. The system consists of auxiliary cooling water heat exchangers, closed-loop cooling system pumps, and a cooling water head tank. With this system, cooling water is continuously recirculated through the shell side of the auxiliary heat exchanger to the various plant coolers such as the hydrogen cooler, lube oil cooler, air compressor coolers, etc. The heat transferred to the auxiliary heat exchanger is either dissipated into the circulating cooler water or to the plant make-up water prior to treatment. A separate auxiliary cooling system may not be required after the circulating cooling water quality is established during design. It may be possible to pump circulating cooling water directly to the equipment coolers. The present design includes an auxiliary cooling system.

5. Make-up Water.

Condensate make-up is provided since boiler drum blowdown will be required to minimize total solids build-up in the feedwater and steam cycle. The make-up water source is from the existing city water main. After treatment, the make-up water would be stored in a condensate storage tank. Make-up water would be pumped to the condenser hot well by two full-capacity condensate transfer pumps.

6. Compressed Air System.

A complete compressed air system is included in the capital cost estimate. Separate systems for service air and instrument (oil-free) air are included. Two full-capacity air compressors for each system are also included. One compressor normally can supply the demand, while the other provides a firm supply and can carry part of the load during times of unusually high demand. Receivers are sized to allow start/stop operation of the compressors without frequent cycling. Aftercoolers are provided on all compressors to ensure a dry air supply. Instrument air is supplied through a refrigeration-type filter-dryer to provide additional drying.

7. Lube Oil Conditioning.

The turbine generator would be furnished with a lubricating oil reservoir, pumps, and piping. Lube oil conditioners and pumps and a lube oil centrifuge would be included.

8. Condenser Vacuum Equipment.

It is assumed that steam jet air ejectors are used to remove the noncondensible gases from the condenser during turbine operation. Mechanical vacuum pumps would be used for evacuating the condenser from atmospheric pressure. The steam jet air ejectors would hold the condenser vacuum during normal operations.

6.5.6 Water Treatment

Chemical conditioning of the circulating cooling water and steam cycle make-up water is required in order to ensure efficient and dependable plant operation. Treatment is generally required to minimize the possibility of fouling and corrosion of the heat transfer surfaces.

Circulating cooling water chemical treatment is assumed to include:

1. Acid feed equipment.
2. Chlorination equipment.
3. Scale inhibitor feed equipment.

Since the make-up water source is the existing city water main, the concentration cycles in the circulating water system can be high (approximately 30 cycles). Scale inhibitors may be required at the high concentration cycles and are included in the design.

The circulating water chemical feed system protects the system components, especially the condenser tubes, against excessive scaling and corrosion. This system also controls slime and algae that can affect heat transfer in the condenser and cause deterioration of cooling tower materials. The chemical feed system includes equipment for feeding sulfuric acid, scale inhibitor, and chlorine into the circulating water. Mechanical tube cleaning can also be used to remove slime and algae, but is most effective in removing scale (calcium deposits).

Cooling tower manufacturers can guarantee that the drift rate of an evaporative cooling tower will be 0.005 percent or less of the circulating water flow rate. Therefore, the drift for the plant is expected to be less than 1 gpm (0.8 gpm) based on a circulating flow rate of 15,500 gpm. Cooling tower drift has the same chemical properties as the water in the cooling towers. During periods of shock chlorination (typically three 20- to 30-minute periods per day), the chlorine concentration in the water will be adjusted to maintain 0.5 mg/L total residual chlorine at the condenser outlet. In addition, it is possible that as much as 50 percent of the chlorine will flash or decompose as it passes through the cooling tower fill. Therefore, during the periods of shock chlorination, the 0.8-gpm drift will contain up to 0.5 mg/L of chlorine. The total amount of chlorine released in the cooling tower drift is an extremely small amount.

Drift deposition studies can be completed during detailed design if it is anticipated that the concentration of solids in the water will cause the drift to be an environmental concern.

Sulfuric acid can be introduced at the cooling tower basin to reduce alkalinity to control the scaling tendency of the circulating water system. To further inhibit scale deposition, organic phosphate can be automatically fed at the cooling tower basin as a sequestering agent.

To prevent biofouling of the circulating water system, chlorination equipment is included for intermittent shock chlorination. A chlorine solution can be fed into the circulating water pump basin through diffusers.

The steam cycle make-up water conditioning is assumed to include softening and corrosion-control chemical injection. For steam pressures between 600 and 1,000 psi, Babcock & Wilcox recommends(10) the following limits for solids in the boiler feedwater:

Item	ppm
Total solids	2,000
Total hardness as $CaCO_3$	0
Iron	0.05
Copper	0.03
Oxygen	0.007
pH	8.0 - 9.5

Demineralization or evaporation of the make-up water is probably not required since the operating pressure is less than 1,000 psi. Softening can be accomplished by using sodium zeolite softeners. These softeners use resin materials that have the capability of exchanging hardness constituents, like calcium and magnesium, for sodium. The pH can be maintained by injecting hydrazine or some other neutralizing amine into the feedwater. Softening the make-up water would minimize the potential for scale buildup and hydrazine injection, and phosphate treatment (low concentration) would possibly maintain the pH in order to prevent corrosion. Hydrazine also acts as an oxygen scavenger. The use of hydrazine requires proper ventilation and care in handling. The actual chemical treatment will be evaluated in more detail during design.

The chemical feed system cost includes all of the equipment, piping, valves, wiring, instruments, controls, etc., for a complete system. The equipment also includes metering pumps, motors, and solution tanks.

6.5.7 Controls and Instrumentation

The design for all controls and instrumentation assumes a complete refurbishment of the existing plant control room in order to coordinate control of the incinerator operations with control of the turbine generator and auxiliary equipment.

The control area will contain the control system cabinets, minicomputer equipment, auxiliary and protective relay equipment, and similar devices. A cable spreading room, through which all control and instrumentation electrical cable and pneumatic tubing will be routed, is planned beneath the control room. The purpose of the control room is to:

1. Provide the control interface between the incinerator, waste heat boiler, and turbine generator.

2. Provide the interface between the generating plant and its operating staff.

3. Provide the interface between the generating plant operation and incinerator staff.

The control room and control panels will be designed to permit safe, reliable, and efficient operation using a minimum number of personnel. The control and instrumentation system is based on utilizing a central plant control room for control of the incinerator operations, as well as the waste heat boilers, turbine generators, and associated auxiliary equipment. A combined benchboard and vertical panel will be used in the control room. The control panels will be modularized so that new panels and controls can be added as required. This concept will also provide a control system based on individual incinerator/waste heat boiler units. Panel equipment will be arranged in functional groupings so that during start-up or emergency situations the responsibility for each separate segment of the plant operating equipment can be assigned to an individual, if required.

System cabinets will be provided for the analog control, computer, sequential events monitor, plant interlock, and other systems. The equipment in these cabinets require a clean, well-lighted, temperature-controlled environment for effective maintenance.

The controls and instrumentation include all waste heat boiler, turbine, generator, and exciter instruments and controls, as well as other instruments and control equipment including:

1. Feedwater controls.

2. Turbine generator bearing monitoring systems.

3. Remote indicators.

4. Temperature recorders.
5. Flow-meters and recorders.
6. Annunciators.
7. Electrical indicators.
8. Panel control switches.
9. Water treatment instruments.
10. Switchyard controls and instrumentation.

6.5.8 Electrical Equipment

The electrical equipment necessary for the turbine generator and balance of plant operation can be divided into two main categories. The first category includes all of the equipment necessary to connect the generator to Consolidated Edison's 27-kV distribution system. The generator output will be stepped up to 27 kV by the generator transformer. Connections between the generator, generator breaker, and generator transformer will be accomplished with an isolated phase bus duct. The bus duct rating will have to be determined during the detailed design phase as the generator voltage will depend on the turbine generator. The generator breaker will be an oil circuit breaker. Connections for the main and reserve auxiliary transformers will be made by tapping the bus duct between the generator breakers and the generator transformer.

The second category includes the main and reserve auxiliary transformers and all switch gear and wiring necessary to supply a new balance of plant equipment. The existing plant switch gear is 480 VAC. With the exception of the circulating water pump motors, the balance of the plant equipment can be started and operated on this line voltage. Instead of installing a high voltage transformer and switch gear for the circulating water pumps, some form of starting compensation can be used. This will limit the 480-VAC system voltage drop and protect the 480-V equipment from damage when the circulating water pumps are started. The 480-V buses will also supply lighting circuits through a 480/120-V transformer. Due to the remote location of the cooling tower, cooling tower fans, lighting, and circulating water pumps will be supplied from a secondary unit substation located near the circulating water pump structure.

The physical location of the new switch gear and the electrical connections of the new and existing equipment should be evaluated in the detailed design of the turbine generator and balance of plant equipment. The adequacy of the existing emergency generator should also be determined during the detailed design effort.

6.5.9 Structural Requirements

Two boiler configurations were identified as being technically feasible; i.e., supporting the boilers directly above the furnaces (using either an external truss or reinforcing the existing structure), or constructing a new building adjacent to the facility to house the boilers and turbine-generator equipment (see Figures 6-4 and 6-5).

The costs associated with the external truss system and the new building option were found to be essentially equal. For the purposes of this study, the proposed design incorporates the external truss system supporting the four boilers directly above their respective furnaces.

As shown on Figure 6-4, a steel truss system approximately 21 feet deep, with an unsupported span of 190 feet, is required to support the four waste heat boilers in this configuration.

A complete structural analysis of the existing incinerator building and foundations should be performed in detailed design; a detailed comparison of various boiler placement options will be made at that time. This could reduce the structural requirements. For the purpose of this feasibility study, the proposed truss support structure is considered a conservative estimate of the structural requirements of this project. Design considerations for this item include all structural steel, foundations, concrete floor slab, reinforcement, and a weatherproof enclosure housing the boilers.

The turbine generator and associated equipment will be located in a new building near the existing maintenance shop at the northwest corner of the incinerator plant. The preliminary equipment arrangements within the turbine building are shown on Figures 6-6 and 6-7. A gantry-type turbine room crane is included in the building. Structural design considerations are based on steel framing and concrete floor pile-type foundations

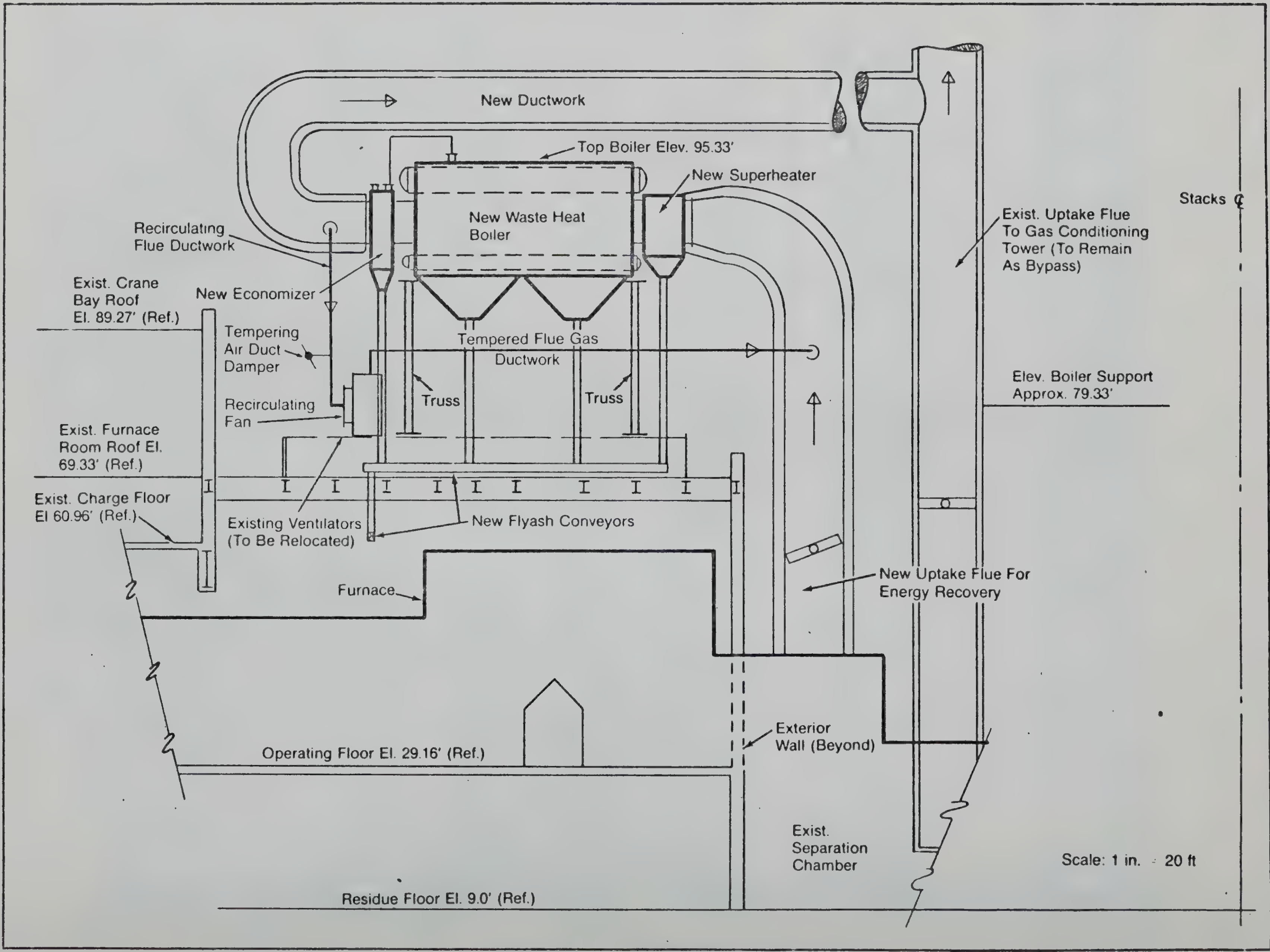

New Ductwork
Top Boiler Elev. 95.33'
New Superheater
New Waste Heat Boiler
Stacks ℄
Exist. Uptake Flue To Gas Conditioning Tower (To Remain As Bypass)
Recirculating Flue Ductwork
New Economizer
Exist. Crane Bay Roof El. 89.27' (Ref.)
Tempering Air Duct Damper
Tempered Flue Gas Ductwork
Elev. Boiler Support Approx. 79.33'
Recirculating Fan
Truss
Truss
Exist. Furnace Room Roof El. 69.33' (Ref.)
Exist. Charge Floor El 60.96' (Ref.)
Existing Ventilators (To Be Relocated)
New Flyash Conveyors
Furnace
New Uptake Flue For Energy Recovery
Exterior Wall (Beyond)
Operating Floor El. 29.16' (Ref.)
Exist. Separation Chamber
Scale: 1 in. = 20 ft
Residue Floor El. 9.0' (Ref.)

FIGURE 6-4 TRUSS ELEVATION

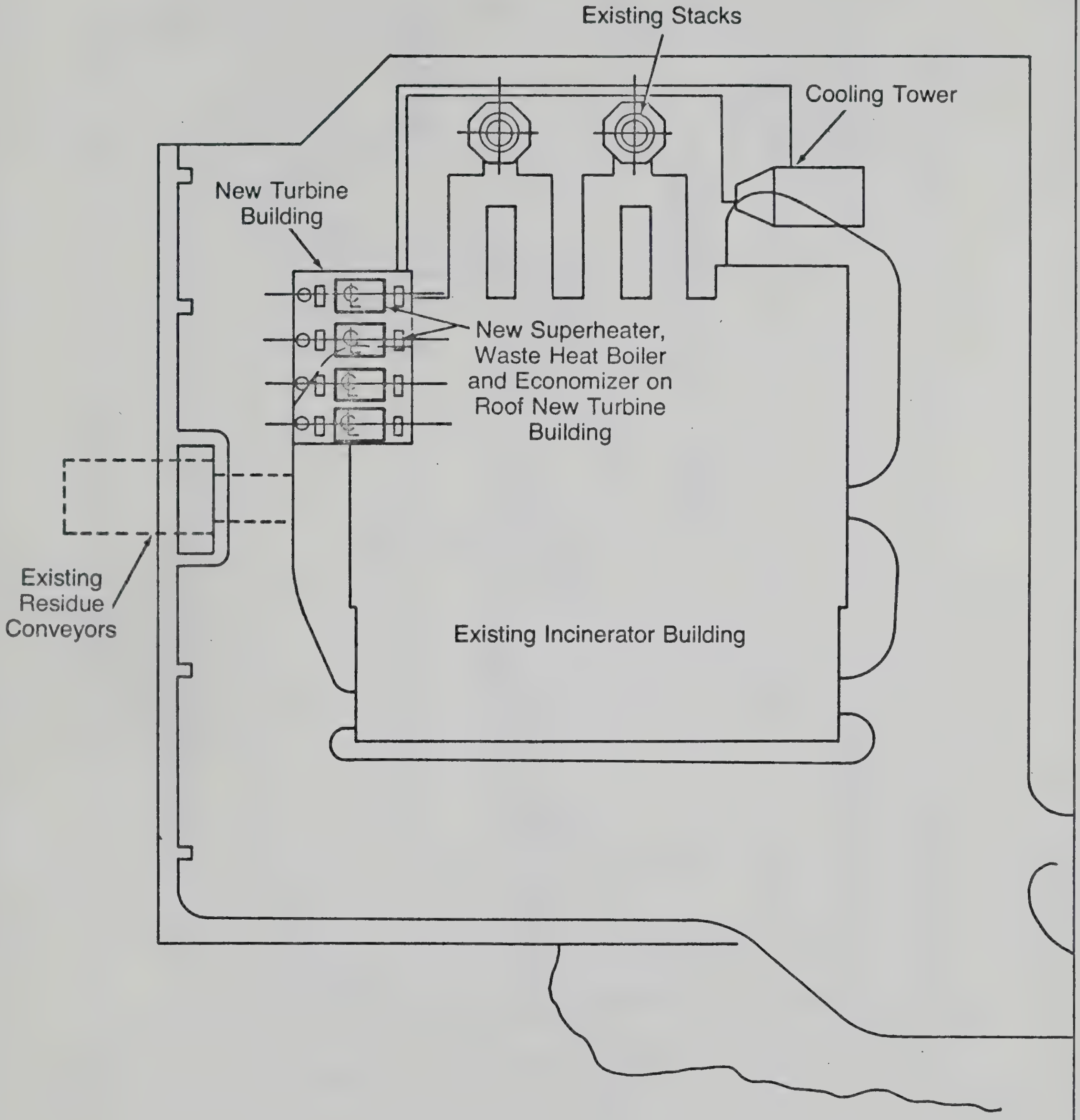

Existing Stacks
Cooling Tower
New Turbine Building
New Superheater, Waste Heat Boiler and Economizer on Roof New Turbine Building
Existing Residue Conveyors
Existing Incinerator Building

FIGURE 6-5 ALTERNATE NEW TURBINE BUILDING ARRANGEMENT

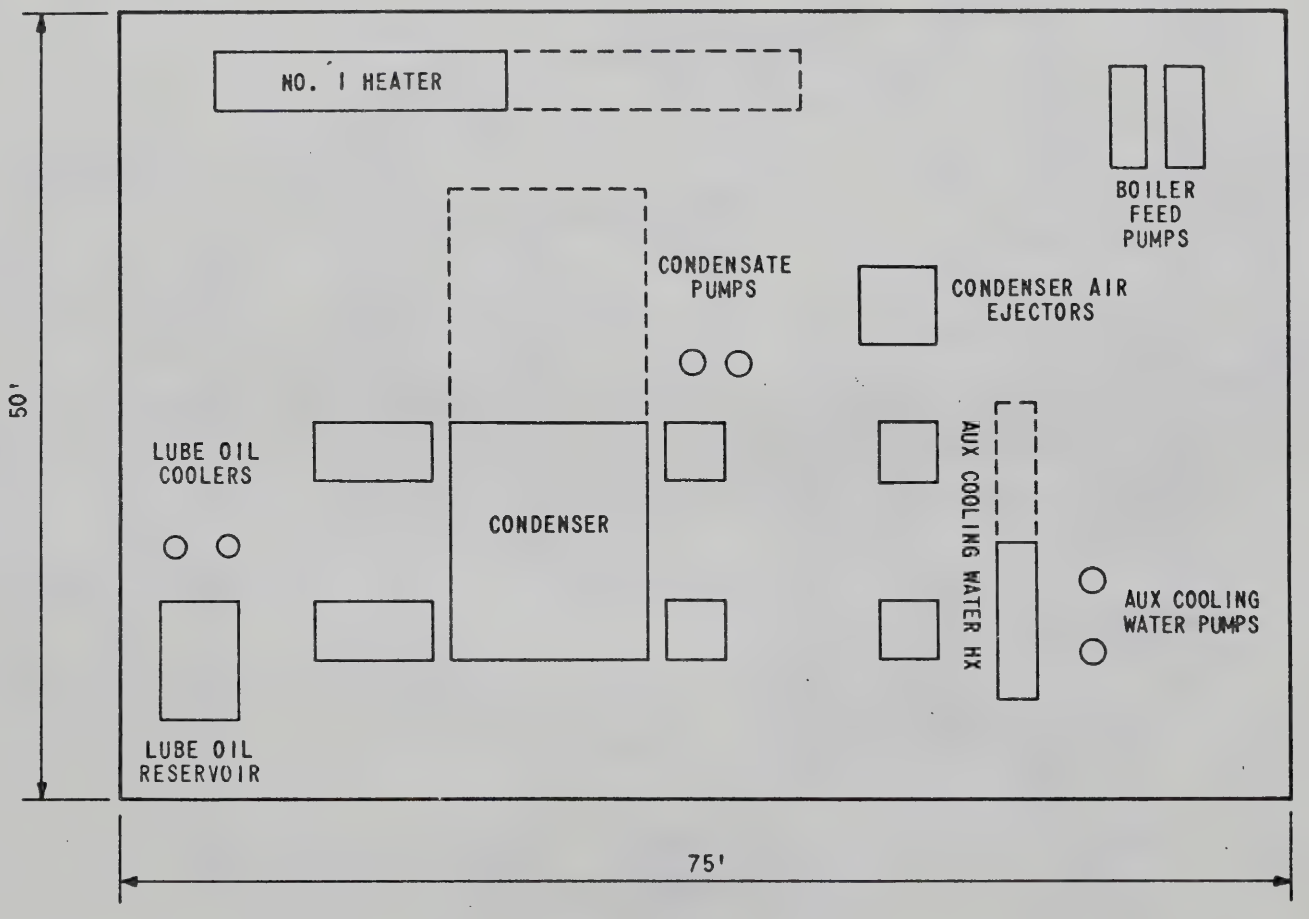
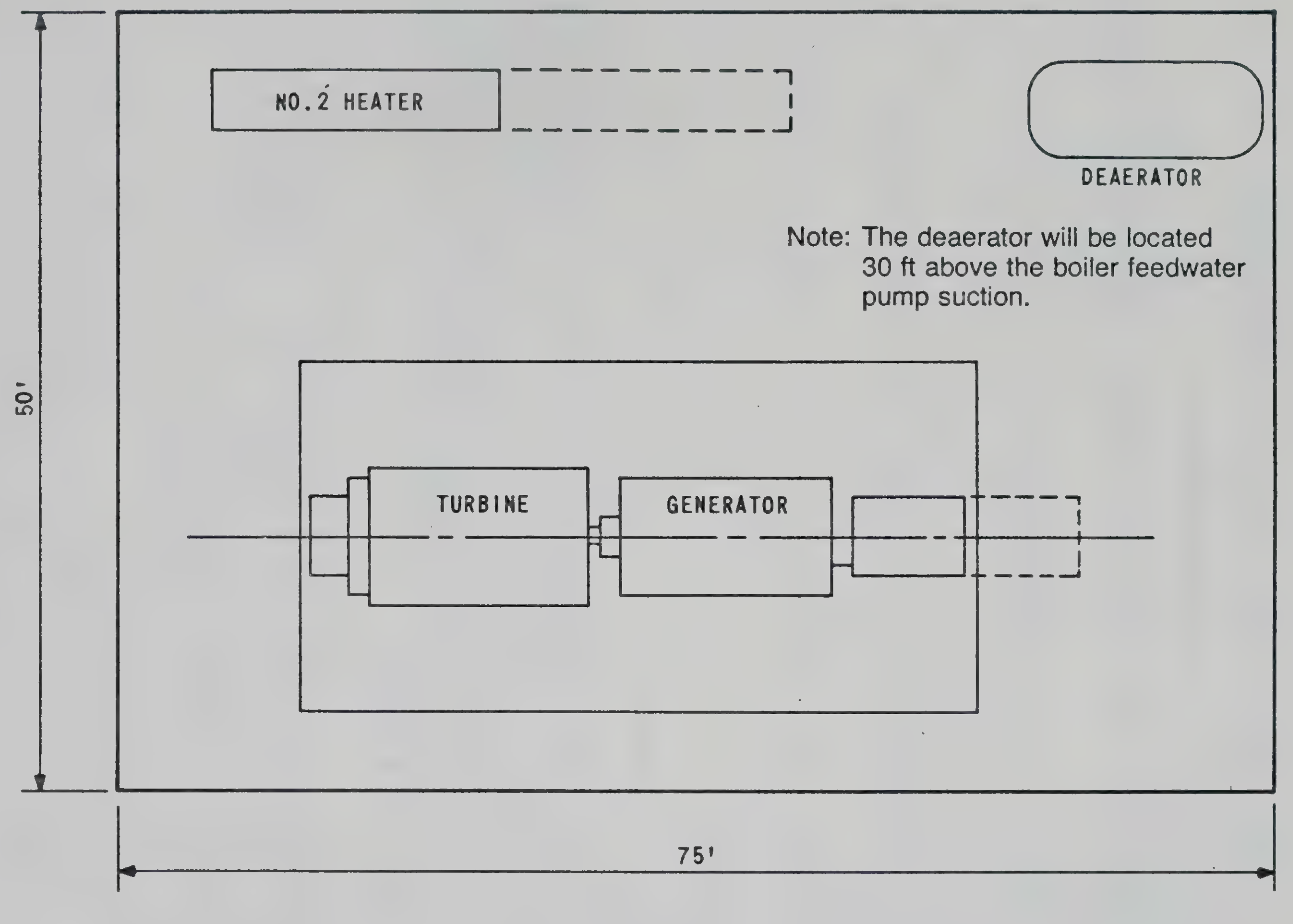


FIGURE 6-6 PRELIMINARY ARRANGEMENT OF TURBINE BUILDING GROUND FLOOR



Note: The deaerator will be located 30 ft above the boiler feedwater pump suction.

FIGURE 6-7 PRELIMINARY ARRANGEMENT OF TURBINE BUILDING—OPERATING FLOOR

supporting the structure. The platforms would utilize steel grating. Typical design features include the following:

1. Sandwich panel-type, insulated metal exterior walls.
2. Hollow metal flush-type doors.
3. Aluminum projected-type windows and pinion-type operators.
4. Floor coverings, as required.
5. Suspended ceilings, as required.
6. Precast concrete roof decks and built-up tar and gravel roofing.
7. Interior partitions of concrete block and metal wall panels.
8. Grating.
9. Handrail and stairs.

To be considered during the final design phase will be the inherent problems of erection and boiler installation, with respect to site constraints, the span of the trusses, lift height, etc. At this time, it is assumed that at least one high-lift, heavy-duty capacity erection crane will be required either on the bay or parkway side. Separate foundations may be required for anchoring this crane.

Adequate heating and ventilation will be provided for work areas as required. Lighting will be consistent with low operation and maintenance costs. This will consist of fluorescent lights for the operating floor and control room, and mercury vapor lights for all other plant areas, as required.

6.5.10 Capital Cost Estimates

The cost summary for the electricity only alternative is presented in Table 6-5. This estimate includes all of the equipment discussed previously. In several instances, the cost estimate is determined based on previous experience with similar sized equipment for 20-MW plants. The estimates for major components

Table 6-5

Capital Cost Estimate -- Electricity-Only Alternative
(September 1981 $)

Equipment	Cost
Waste Heat Boilers and Enclosures[1]	$ 1,825,000
Support truss	2,533,000
Flue Gas Breeching	3,487,000
Induced Draft Fans	1,716,000
Fly Ash Conveyors	181,000
Recirculation Dampers and Connections	580,000
Underfire Air Fans	60,000
Turbine Generator	3,100,000
Condenser	280,000
Air Ejectors	20,000
Feedwater Heaters	90,000
Deaerator	70,000
Condensate Pumps	15,000
Boiler Feed Pumps	100,000
Condensate Piping	50,000
Feedwater Piping	120,000
Miscellaneous Water Pumps	50,000
Main Steam Piping and Valves	150,000
Extraction Piping and Valves	50,000
Bypass System	55,000
Cooling Tower	1,500,000
Pump Structure	150,000
Circulating Water Piping	340,000
Circulating Water Pumps and Motors	275,000
Auxiliary Cooling Water System	30,000
Compressed Air	50,000
Fire Protection System	25,000
Condensate Storage and Transfer	60,000
Water Treatment[2]	180,000
Air Preheaters	127,000
Control Equipment	1,100,000
Electrical Equipment	1,100,000
Turbine Building and Foundations	1,125,000
Mechanical Construction[3]	3,408,000
Electrical Construction	2,700,000
Insulation of Gas-Conditioning Tower and Recirculation System	270,000
Total Installed Equipment Cost	$26,972,000

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[1] For vendor cost information see Appendix J.

[2] Includes chemical addition system.

[3] Includes plant communication system and additional heating systems.

such as the waste heat boilers, turbine generator, pumps, cooling towers, and induced draft fans were obtained from manufacturers' quotations based on the size of the equipment. The costs presented include the price of the equipment and erection costs, expressed in September 1981 dollars.

The capital costs presented in Table 6-5 include the use of a cooling tower as part of the heat rejection cycle equipment. An alternative arrangement could utilize water from Gravesend Bay in a once-through cooling system.

6.6 ELECTRICITY AND STEAM COGENERATION -- CONCEPT AND COSTS

In this alternative, main and extraction steam will be used to supply thermal energy to a district heating network. This system will be used to supplement existing space heating systems in the district. These existing systems will be required to meet peak demands.

The basic district heating steam requirements have been presented in Section 5. The distribution steam is to be generated in an evaporator installed in the new turbine building. The use of cycle extraction steam directly for district heating steam is not considered feasible since the steam would be contaminated during its flow through the district steam loop, resulting in condensate treatment costs which could be prohibitively expensive. It is assumed, however, that 95 percent of the district steam is returned as condensate. The remaining 5 percent is assumed to be lost from the system. Make-up water would come directly from the City water supply with possibly some preheating utilizing boiler blowdown. The site layout for this alternative is identical to that presented on Figure 6-2.

6.6.1 Waste Heat Boilers

The modifications and equipment required to implement waste heat recovery in a cogeneration mode are identical to those proposed in subsection 6.5.1. Steam produced in the waste heat boilers will be conveyed, as before, to the turbine. As in the electricity-only alternative, the waste heat boilers will be supported by a truss system spanning the existing incinerator building. Structural requirements and associated costs are identical for both the electricity-only and cogeneration modes.

6.6.2 Turbine Generator

The turbine generator for this alternative will be an automatic extraction type. The automatic extraction will maintain the extraction steam pressure at a fixed value. This extracted steam will be used to generate steam for the district heating loop in an evaporator installed specifically for this purpose. Automatic extraction turbines include additional internal governing valves and a steam chest following the extraction stage in order to maintain the extraction pressure by throttling the flow at off-design conditions.

Automatic extraction turbines are more expensive and less efficient than similar sized straight-through condensing turbines due to the additional extraction outlet, governor valves, and steam chest.

The turbine extraction is designed to supply 134,000 lbs/hr at 290 psig for the full steam loop, and 57,000 lbs/hr at 230 psig for the partial steam loop.[1]

6.6.3 Balance of Plant Equipment

Evaporators using steam as the heating medium can be constructed with approach temperatures as low as 10°F. The approach temperature is the difference between the extraction steam temperature and the steam temperature supplied to the district heating system. As the design approach temperature of the evaporator decreases, the extraction flow required decreases, but the evaporator size and cost increase. For this study, a representative approach temperature (at design) of 40°F is used.

When high-pressure superheated steam is used as the extraction steam source, some amount of throttling and desuperheating spray is required. Evaporators become prohibitively expensive if superheated steam is used directly. Therefore, the evaporator arrangement would use attemporation spray from the boiler feed pumps. The recommended evaporator flow schematics for both district heating plans (full and partial steam loops) and heat balances are shown on Figures 6-8 and 6-9.

There are two feasible extraction steam sources available for this arrangement. One source is main steam supplied directly

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[1] Steam load conditions for the partial and full steam loops are presented in detail in Section 5.

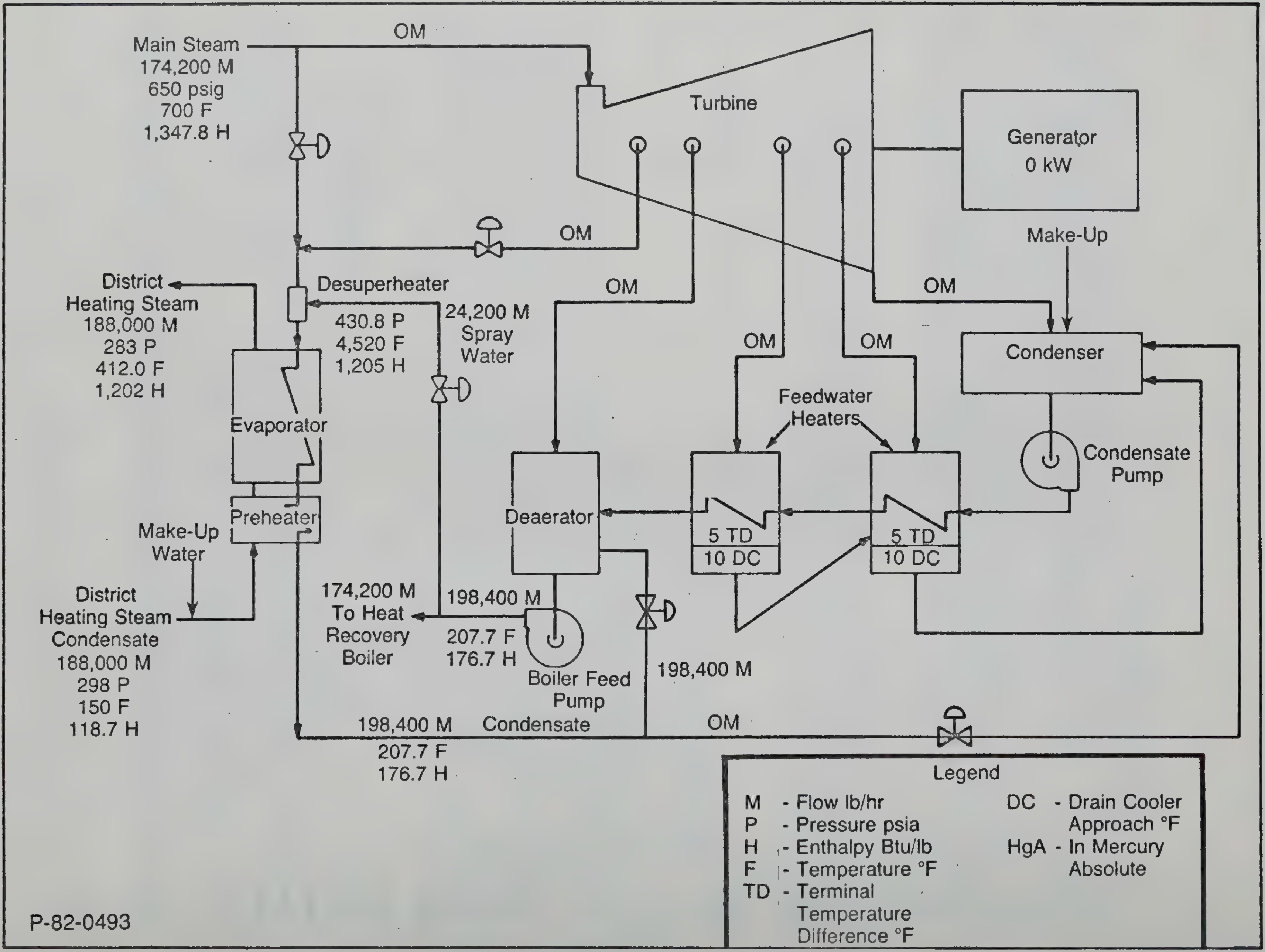

FIGURE 6-8 FLOW SCHEMATIC WITH EVAPORATOR: FULL LOOP -- PEAK DISTRICT HEAT REQUIREMENT

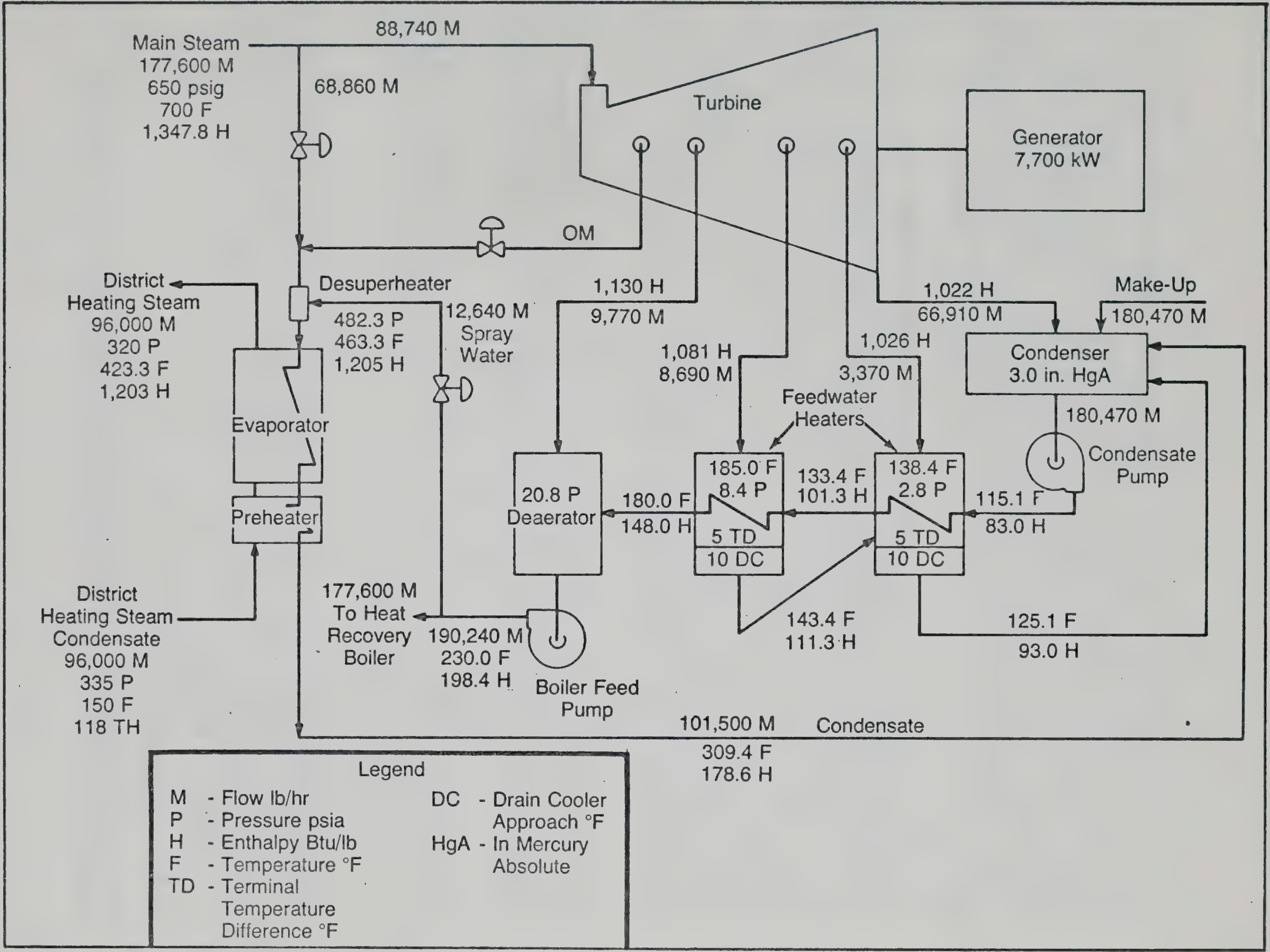

FIGURE 6-9 FLOW SCHEMATIC WITH EVAPORATOR: PARTIAL LOOP -- PEAK DISTRICT HEAT REQUIREMENT

from the waste heat boilers and the other source is an interstage high-pressure turbine extraction. Based on the distribution system pressures and flow rates required for the district steam systems, both sources were evaluated. The main steam source is used for high-pressure, high-flow district heating requirements, and the interstage extraction is used for low-pressure, low-flow district heating requirements. This arrangement provides the most advantageous steam and electricity generating plan.

For the purposes of this study, high-pressure main steam is used as required to satisfy district heating requirements in excess of 60 percent of the peak heating load. When main steam is more than sufficient for district heating requirements, the remaining main steam is introduced to the turbine for electrical generation. For the full loop, there is insufficient main steam to generate the peak district heating steam requirement. The maximum steam generation rate is 185,200 pph of district heating steam which results in a peak shortage for approximately 650 hrs/year. During this period no electricity is generated. For the partial loop there is sufficient main steam for the peak requirement and generation of electricity.

Below 60 percent of the peak heating requirement, the evaporator charging steam is run through the turbine for steam pressure reduction and electrical generation. The extraction pressure is dependent on the final selection of the district heating steam flow to be generated by turbine extraction.

The district heating loops will return the condensate to an onsite storage tank. From this tank, the condensate is pumped to the evaporator preheater and then to the evaporator where steam is produced for district heating.

The evaporator charging steam, taken from the main steam line or the high-pressure turbine extraction, is condensed in the evaporator. This condensate is used to preheat the district heating system condensate. The charging steam condensate then drains to the condenser by the pressure differential between the evaporator and the condenser.

6.6.4 Cost Summary

The cost summary for the electricity and steam options (turbine generator and balance of plant equipment) are shown on Table

6-6. The cost changes from the previous summary (Table 6-5) include the following items:

1. Turbine generator.
2. Evaporator.
3. Miscellaneous water pumps.
4. Feedwater piping.
5. Extraction piping and valves.
6. Condensate storage and transfer.

Table 6-6

Capital Cost Estimate -- Cogeneration Alternative
(September 1981 $)

Equipment	Full Steam Loop	Partial Steam Loop
Waste Heat Boilers[1]	$ 1,825,000	$ 1,825,000
Support truss	2,533,000	2,533,000
Flue Gas Breeching	3,487,000	3,487,000
Induced Draft Fans	1,716,000	1,716,000
Fly Ash Conveyors	181,000	181,000
Recirculation Dampers and Connections	580,000	580,000
Underfire Air Fans	60,000	60,000
Turbine Generator	3,350,000	3,350,000
Condenser	280,000	280,000
Air Ejectors	20,000	20,000
Feedwater Heaters	90,000	90,000
Deaerator	70,000	70,000
Condensate Pumps	15,000	15,000
Boiler Feed Pumps	100,000	100,000
Condensate Piping	50,000	50,000
Feedwater Piping	125,000	125,000
Miscellaneous Water Pumps	70,000	60,000
Main Steam Piping and Valves	150,000	150,000
Extraction Piping and Valves	75,000	65,000
Bypass System	55,000	55,000
Cooling Tower	1,500,000	1,500,000
Pump Structure	150,000	150,000
Circulating Water Piping	340,000	340,000
Circulating Water Pumps and Motors	275,000	275,000
Auxiliary Cooling Water System	30,000	30,000
Compressed Air	50,000	50,000
Fire Protection System	25,000	25,000
Condensate Storage and Transfer	75,000	70,000
Water Treatment[1]	180,000	180,000
Air Preheaters	127,000	127,000
Control Equipment	1,100,000	1,100,000
Electrical Equipment	1,100,000	1,100,000
Turbine Building and Foundations	1,125,000	1,125,000
Mechanical Construction[1]	3,408,000	3,408,000
Electrical Construction	2,700,000	2,700,000
Evaporator	340,000	225,000
Insulation of Gas-Conditioning Tower and Recirculation System	270,000	270,000
Total Installed Equipment Cost	$27,627,000	$27,487,000

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[1] See Table 6-5, footnotes 1,2, and 3.

SECTION 7

MATERIALS RECOVERY

7.1 INTRODUCTION

Materials recovery offers the benefits of a revenue-generating product as well as the reduction or elimination of the environmental problems associated with final disposal.

Section 7 addresses the technical feasibility and potential for marketing the incinerator residue remaining after combustion at the Southwest Brooklyn Incinerator.

7.2 INCINERATOR RESIDUE

The composition of municipal refuse is influenced by several dynamic factors including climate, season, standard of living, source storage methods, local packaging practices, and industry types. Residue composition is affected by the refuse, the basic design of the furnace and burning grates, as well as charging rate, forced air distribution, and ash quenching techniques.

Incinerator residues are classified on the basis of combustion efficiency, or degree of burn-out. The degree of burn-out is defined as the ratio of the incinerated portion to the original combustible fraction of the raw refuse.(11) Residue produced by continuous-fed incinerators incorporating reciprocating grates (i.e., Southwest Brooklyn) is generally classified as well burned out and consists of 20 to 30 percent by weight of the refuse input, and approximately 5 to 15 percent of the refuse volume. During several site visits to the Southwest Brooklyn Incinerator, this good burn-out has been verified by visual observation. Material recovery concepts presented in subsequent subsections are based on a residue weight fraction of 20 percent of the incoming refuse, or 200 tpd.

Studies performed by the U.S. Bureau of Mines on residue samples from municipal incinerators in the Washington, D.C., area are summarized in Table 7-1. Incinerator residue consists mainly of ferrous and nonferrous metals, ash, glass, and stone. Smaller fractions of unburned paper and partially-burned organics are a function of incinerator operation and equipment efficiency.

Table 7-1

Composition of Incinerator Residue

Material	Dry Weight %	Bulk Density[1] lb/cu yd	Projected Quantities at Southwest Brooklyn tpd
Tin cans	17.2	197	56
Mill scale and small iron scrap	6.8	2,329	
Iron wire	0.7	NR[2]	
Massive iron scrap	3.5	NR	
Nonferrous metals	1.4	NR	3
Stones and bricks	1.3	1,845	124
Ceramics	0.9	1,431	
Ash	15.4	582	
Glass	44.1	2,037	
Unburned paper and charcoal	8.3	NR	18
Partially-burned organics	0.7	NR	

Source: "Composition and Characteristics of Municipal Incinerator Residues," U.S. Department of the Interior, Bureau of Mines, Report of Investigations No. 7204, December 1968.

[1] Bulk densities calculated for loosely packed, dry materials.

[2] Not reported.

Incinerator residue which is quenched prior to plant discharge may also have a significant moisture content. This moisture content is a function of the method of quenching, the age of the residue, and the relative amount of combustible material contained in the residue. Surveys performed for the Federal Highway Administration (FHWA) indicate the average moisture content of municipal incinerator residue to be approximately 33 percent.(15)

7.3 FERROUS METALS

A residue analysis performed by the Bureau of Mines indicated a total ferrous metal content of 28.2 percent. Based on the incinerator's residue production rate of 200 tpd (at full capacity), 56 tpd of ferrous metals is contained in the residue (Table 7-1).

Once the residue has undergone incineration, most of the entraining materials have been removed and a simple magnetic drum separator can provide adequate classification of the residue stream. Relatively small equipment can be used in this separation since the refuse has undergone a significant volume reduction (approximately 90 percent) in the furnace.

Utilization of ferrous scrap which has been incinerated is limited to the production of ferroalloys. This is due to the impurities added to the ferrous in the incineration process (i.e., primarily copper contamination and diffusion of tin into the steel, preventing subsequent removal by standard detinning practices).(12) Although copper and tin can affect the rolling and mechanical properties of steel, the severity of this contamination varies with the steel product, composition, and processing techniques used.

Studies performed by the Bureau of Mines(13) have indicated that steels manufactured using reclaimed ferrous scrap exhibited acceptable surface and edge conditions and rolled successfully. Tensile strengths of plain carbon steel were not significantly affected by copper concentrations up to 0.65 percent and tin concentrations up to 0.16 percent. Yield strength increased as these concentrations increased; impact strength was decreased with increasing tin content. Hardness was found to increase slightly with increasing copper content. In general, the properties of the steels produced were not measurably affected by melting stock composition, melting practice, or method of scrap preparation. These studies were performed using electric furnaces which are less susceptible to high impurity levels in the feedstock. In the older, conventional furnaces, these impurities tend to precipitate and attach to the bottom refractories, thereby increasing system maintenance requirements.

7.4 NONFERROUS METALS

On the basis of Bureau Mines data (Table 7-1), the residue from the Southwest Brooklyn Incinerator contains approximately 3 tpd of nonferrous metals, approximately 70 percent of which is aluminum. Of the remaining 30 percent, the majority is copper and zinc, contained in discrete nuggets of coarse and fine sizes. Typical compositions of heavy nonferrous metals smelted from incinerator residue products yield copper and zinc concentrations of 55 percent and 36 percent, respectively.

Due to the introduction of impurities, aluminum recovered from incinerator residue is only recommended for use in the production of alloys. Several independent evaluations(14) have been made on recovered aluminum which indicated that the metal could be used to produce a good commercial alloy of the 3105 type used in the construction industry. It should be noted that this metal could be used in the production of most of the alloys produced at secondary smelters. Composition testing of several aluminum samples indicated these materials would also be suitable for producing 380 alloy, which is one of the largest tonnage products manufactured by secondary aluminum smelters.

The quality of recovered aluminum is dependent on the temperature of incineration. Since lower temperatures produce the highest quality metal, the decision to reclaim aluminum from residue may be inconsistent with other resource recovery (e.g., steam production) strategies in the incinerator.

Separation systems for nonferrous metals are complex and capital-intensive. Physical separation is affected by density differences between the metal and heavy media solutions. Although technically feasible, this technology is still under development and has not been applied on a large scale. For this reason, subsequent economic evaluations were not performed.

7.5 NONMETALLIC RESIDUE

Approximately 124 tpd of the 200 tpd of residue produced at the incinerator consists of ash, glass, stones, bricks, and ceramics. Of this material, glass and ash make up the largest proportion. Using Bureau of Mines figures, the remainder of the residue (stones, bricks, and ceramics) is estimated to be approximately 5 tpd.

Unprocessed residue has been used as aggregate material in road construction and concrete production. The ash, glass, and mineral matter which remain after metal separation has been shown to be suitable for use as a base material for road construction, and a substitute for aggregate materials in bituminous mixtures. Glass separated from incinerator residue has also been tested as aggregate in the production of lightweight structural concrete and glass-polymer piping.

Incinerator residue was used in road construction in Brooklyn during and immediately after World War II. Currently, the Department of Sanitation utilizes some of this material for landfill roads. Numerous studies have been performed by the Federal Highway Administration in Chicago, Illinois; Houston, Texas; Washington, D.C.; Harrisburg and Philadelphia, Pennsylvania; and, Baltimore, Maryland, using "as received" and processed resdue as an asphalt aggregate with positive results.(16)

New potential markets for incinerator residues are being investigated for the use of separated glass as lightweight aggregate in the production of concrete blocks, glass-polymer composite pipe, and low-cost bulk insulation material. Devices such as air tables and planers, commonly used in the separation of ores, provide glass separation. Concrete blocks produced from glass aggregates are significantly lighter than most manufactured using regular aggregate, and exhibit a 30 to 40 percent improvement in insulative value.(17) ASTM tests performed on concrete cylinders using lightweight glass aggregate indicate an average compressive strength well above the minimum 2,500 psi required for structural-grade lightweight concrete.

The Brookhaven National Laboratory has developed a glass-polymer composite pipe which exhibits superior compressive strength and increased corrosion resistance. Although the production economics are presently being studied, test sections of this pipe have been installed in New York and New Jersey sewer lines and have operated satisfactorily.

Experiments using unprocessed incinerator residue as an aggregate material for concrete construction have not been successful. Nonferrous metals in the residue, particularly aluminum, were reported to react with the concrete to form hydrogen gas. This gas production results in a significant loss in compressive strength due to the formation of gas pockets, and results in concrete which is much more susceptible to surface spalling.(18)

7.6 MARKET ANALYSIS

Potential markets for ferrous metals and incinerator aggregate (which includes ferrous, nonferrous, and nonmetallic residues) generated at the Southwest Brooklyn Incinerator were investigated.

7.6.1 Ferrous Metals

Market conditions for ferrous scrap reclaimed from incinerator residue are variable and fluctuate with locale and economic conditions. Examples of facilities reclaiming ferrous metals from mass-burning incinerators are listed in Table 7-2.

The installation at Saugus, Massachusetts, operates a back-end ferrous recovery system utilizing a rotating trommel screen with 1-inch openings. Oversize materials from the screen are separated by a magnetic drum. Although specific details of the metal marketing contract are confidential, this agreement includes a minimum or "floor" price, a take-or-pay clause, and a selling price indexed to the market price of No. 2 scrap bundles. The current selling price is well in excess of $7.00/ton.(19)

Metal recovery systems installed at Harrisburg, Pennsylvania, and Chicago, Illinois, are presently operating without suitable markets. Both plants had contracts with secondary metal processors which have gone bankrupt. The staff at the Harrisburg plant presently stockpiles the recovered metal on-site; Chicago is presently paying a nominal amount for disposal, but negotiations are ongoing with a scrap metal dealer.

The facility at Pinellas County, Florida, is presently under construction and is expected to be completed in 1983. A preliminary market analysis performed in 1980 indicated a large market exists for recovered ferrous in the Tampa Bay area. No negotiations are ongoing; present plans call for finalization of market contracts after completion of the facility. Preliminary price quotes for reclaimed ferrous metal averaged $20/ton.(20)

Table 7-2

Facilities Utilizing Ferrous Recovery from Incinerator Residue

Location	Refuse Process. Rate tpd	Ferrous Recovery tpd	Type of System	Final Market	Current Price $/ton	Contact
Saugus, MA	1,200	84	Trommel/ drum	Scrap dealer	> $7	Ken Batton
Chicago, IL	1,200	78	Drum	None	Paying for disposal	Emil Nigro
Harrisburg, PA	720	65	Drum	Stockpiling	$0	Carl Albert
Pinellas County, FL	2,000	Under construction	N/A	Industry	$20	Don Acenbrack

Through contacts with the Institute of Scrap Iron and Steel (ISIS), a large dealer/exporter of scrap iron has expressed a strong interest in formulating an agreement with the City of New York to purchase incinerated scrap recovered from the Southwest Brooklyn Incinerator. Under the terms of this agreement, the scrap dealer would supply suitable storage containers for the metal and provide transportation off-site. The City would receive "nominal" payment for the material, approximately $5 to $6/gross ton (gross ton = 2,240 pounds) F.O.B. Southwest Brooklyn based on December 1980 market values and interest rates. The scrap dealer under contract to Saugus, Massachusetts, has also expressed an interest in purchasing the incinerated scrap under a similar agreement, but at a significantly higher price (approximately $12/ton).

7.6.2 Incinerator Aggregate

Each option for utilization of incinerator aggregate (residue) presented in subsection 7.5 was evaluated with regard to technical viability and the potential for market penetration. Technical viability was assessed by means of a qualitative evaluation of anticipated processing difficulties, and the status of product development. For example, minimum processing requirements and more favorable operating or testing history resulted in a more favorable evaluation. Market penetration potential was assessed by considering markets within the vicinity of the Southwest Brooklyn Incinerator and their willingness to accept incinerator residue as a raw material. A summary of this evaluation for various screened residue options is presented in Table 7-3. The recovery of screened residue as a bituminous aggregate extender was judged to have the greatest potential for successful implementation.

In 1979, the Federal Highway Administration investigated the economic feasibility of using incinerator residue in lieu of or as a supplement to aggregates in road and highway construction in several metropolitan areas. This analysis indicated that the utilization of unfused residue as bituminous aggregate(21) is economically feasible in the entire five boroughs of New York City (with the exception of the southernmost tip of Richmond). The study estimated the total aggregate consumption for the New York metropolitan area (including Putnam, Rockland, and Westchester Counties in New York, and Bergen County, New Jersey) at 8.33 million tons in 1979, with a projected increase of 11 percent by 1990. The average price paid for this material in 1979, including barging, was $5.65/ton. Contacts with the New York City Department of Transportation (DOT), the Asphalt Institute,

Table 7-3

Evaluation of Potential Markets for Screened Residue

Option	Comment	Potential for Market Penetration
Lightweight structural concrete	Glass separation required. No operating history.	Poor
Structural fill	Leaching environmental problems. Compaction and workability concerns.	Poor
Glass polymer piping	Glass separation required. Experimental status.	Poor
Aggregate extender in asphalt production	Use as base course for road. Need lime addiction. Extensively studied by Federal Highway Administration. Test cases show feasibility of utilizing all fractions residue.	Good
Concrete aggregate	FHWA testing showed poor results. Portland Cement Institute (PCI) declared it undesirable for utilization.	Poor

and local asphalt plants indicated the average 1981 price to be approximately $10/ton. In New York City, the bulk of aggregate used for construction is barged rather than trucked to the processing site or asphalt plants. This would greatly facilitate the use of residue from incinerators which presently incorporate barge-loading facilities.

The technical viability of utilizing incinerator aggregates in bituminous mixtures has also been demonstrated by the Federal Highway Administration.(22) The New York City Asphalt Plant at Hamilton Avenue provides an accessible market for the Southwest Brooklyn Incinerator residue.

Since the asphalt plant and incinerator are owned and operated by City agencies, institutional arrangements required in such a venture are simplified. Discussions with the New York City Department of Transportation (Highway Department) were initiated for utilizing incinerator aggregate in its operations. The Hamilton Avenue Asphalt Plant has a design capacity of 7,200 tpd of asphalt. Most of the asphalt generated is for use as a wearing course as opposed to a base course where most previous testing of incinerator residue has been focused. Considering the small quantity of aggegate which would be contributed by the Southwest Brooklyn Incinerator (200 tpd), an appropriate mix of incinerator residue and aggregate could be formulated to ensure that Department of Transportation specifications are met. Appendix G presents a detailed outline of the proposed testing program for formulating the desired mix.

Some processing of the residue is required prior to its use as a subbase or aggregate supplement. Preparation of the residue requires removing miscellaneous debris which would decompose or hinder the workability of the material. For well-burned residue, removal of these objects (e.g., metal cans, large pieces of wood) can be accomplished by a combination of screening and magnetic separation. Removal of all objects whose largest dimension is 3 inches would eliminate most, if not all, of this debris. However, the residue will be a better aggregate material if the maximum particle size is reduced to 2 inches or less. On the average, approximately 4-6 percent of pulverized lime should be added to the residue to act as a stabilizer and binder. Pugmill processing is required to screen the admixture to acceptable highway specifications. In addition, the absorptive properties of the residue cause an increase in the asphalt demand of about 2 percent, as compared to virgin materials.

7.7 MATERIALS RECOVERY CONCEPT DESIGN

Five alternative process flow schemes were evaluated for materials recovery at the Southwest Brooklyn Incinerator and are described in the following subsections. The five alternative schemes include three partial material recovery options in which a portion of the residue is recovered and the remaining part is barged to Fresh Kills, and two total recovery concepts where all of the residue is recovered and barging to Fresh Kills is eliminated. Capital and operating cost estimates are presented for each alternative.

7.7.1 Partial Recovery Concepts

Three concepts were evaluated which incorporate recovery of ferrous metals and/or residue aggregate materials. In each of these alternatives, a portion of the residue is returned to the existing disposal barge for landfilling. A general site plan for these alternatives is presented on Figure 7-1.

7.7.1.1 Alternative 1 -- Ferrous Materials Recovery.

This process incorporates a rotating trommel screen to remove grit and small (<1 1/2-inch) objects from the residue to provide a cleaner ferrous product. Oversize materials from the screen are passed under a rotating drum magnet which diverts the ferrous materials to a storage hopper for ultimate resale. Undersize materials from the trommel and nonferrous materials are collected in the existing barge for landfill disposal. Figure 7-2 illustrates this process concept.

7.7.1.2 Alternative 2 -- Aggregate Recovery.

In this concept, incinerator residue is passed through a trommel screen allowing rocks, grit, ceramics, ash, and small ferrous materials, to pass through. This undersize residue is mixed with 4-6 percent lime and conveyed to a barge for transport to the asphalt facility. Oversize residue is conveyed back to the existing barge for landfill disposal. This process is shown on Figure 7-3.

7.7.1.3 Alternative 3 -- Ferrous and Aggregate Recovery.

This alternative combines Alternatives 1 and 2 into an integrated recovery system. Incinerator residue is screened by a rotating trommel. Undersize material is mixed with lime and conveyed to a barge for transport to the asphalt facility.

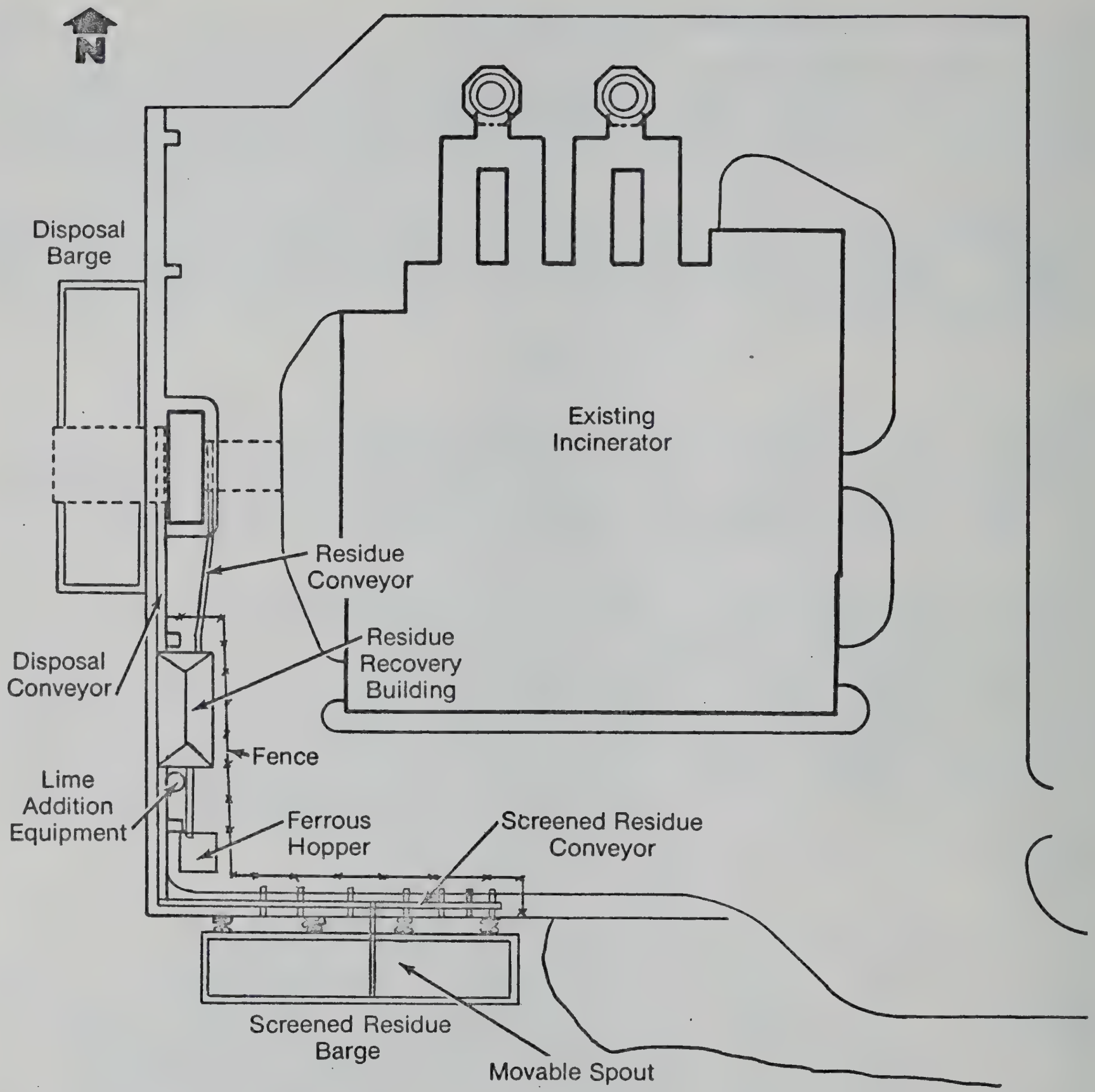


FIGURE 7-1 SITE LAYOUT PARTIAL RECOVERY OPTIONS

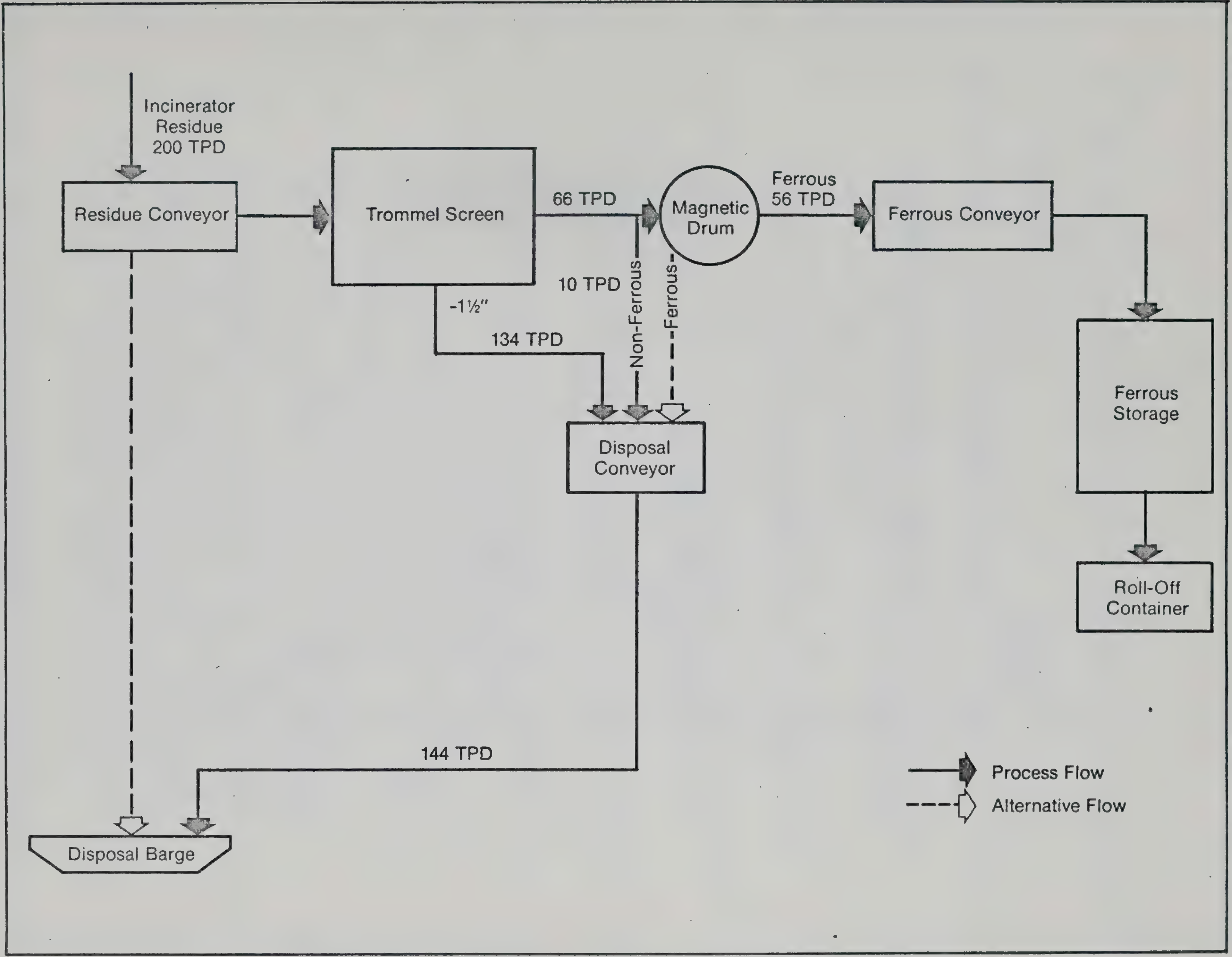


FIGURE 7-2 ALTERNATIVE 1: FERROUS MATERIALS RECOVERY

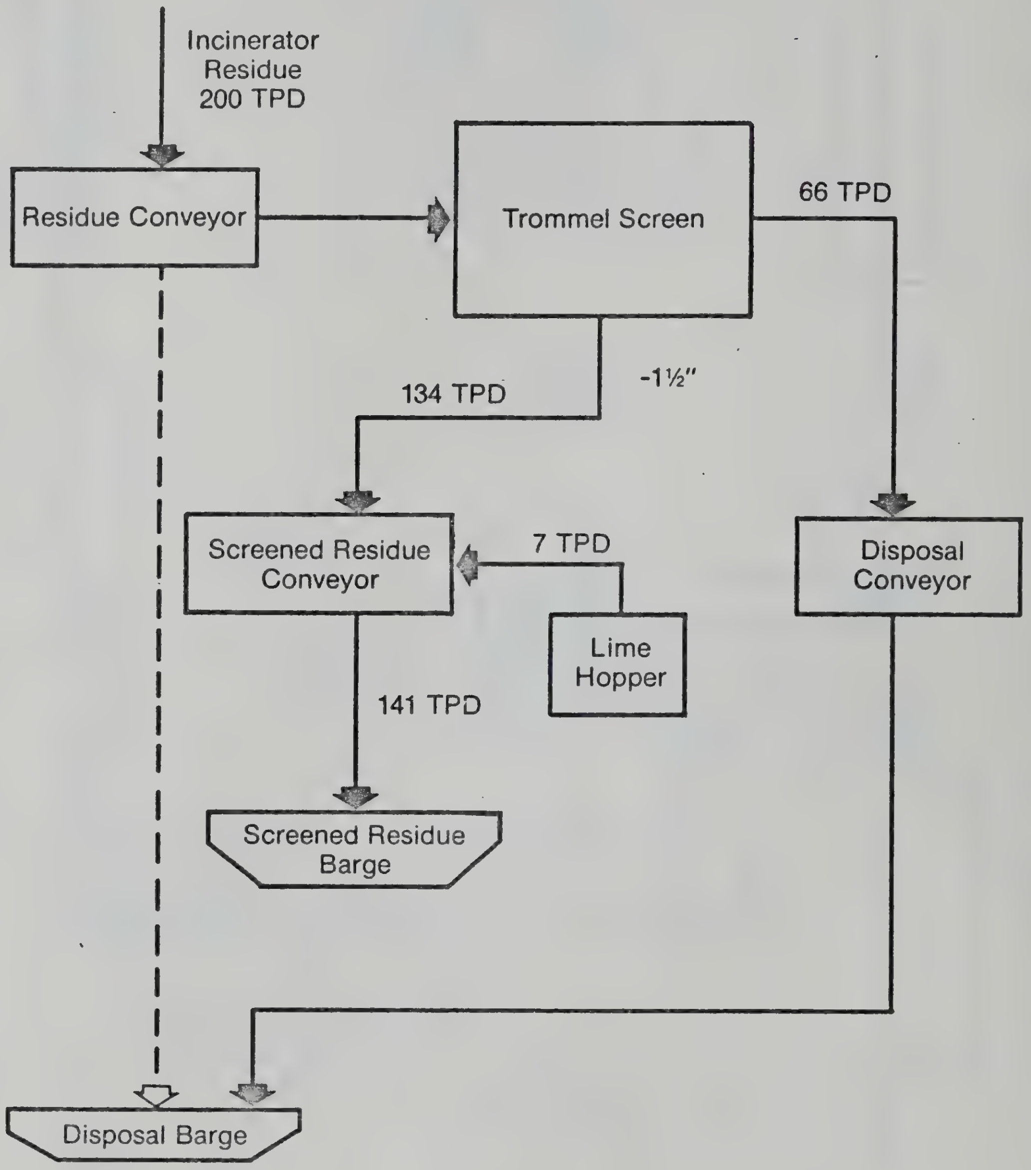


FIGURE 7-3 ALTERNATIVE 2: AGGREGATE RECOVERY

Oversize materials are magnetically separated; ferrous materials are returned to the existing barge for disposal. This alternative is illustrated on Figure 7-4.

7.7.2 Major Equipment

Descriptions of the major components of Alternatives 1 through 3 as they appear in Table 7-4 are as follows:

1. Trommel screen -- Includes a rotating trommel screen with 1 1/2-inch circular openings, complete with foundations, spray system and drain, motor drive, and inlet/outlet chutes.

2. Bifurcated hopper -- Consists of a collection hopper below the trommel screen with dual discharges to separate delivery chutes.

3. Delivery chutes -- Steel chutes which convey undersize materials from the trommel hopper, or bifurcated hopper to either disposal conveyor.

4. Magnetic separator -- Consists of a permanent magnet ferrous metal separation drum with magnesium casing, motor and drum drive, and support structure.

5. Ferrous storage hopper -- Used to contain separated ferrous prior to marketing. This steel hopper has a nominal capacity of 150-cubic yards, or approximately 24 hours of storage. The approximate dimensions of the hopper are 16 feet x 16 feet x 16 feet; suitable access is provided for 50-cubic yard roll-off containers to be filled from a chute on the underside of the hopper.

6. Reject chute -- Collects nonferrous materials rejected by the magnetic drum and diverts this material to the disposal conveyor.

7. Belt conveyors -- Used to transport residue from the existing barge conveyors to the new materials recovery facility; from the building to the disposal and screened residue barge; and to the ferrous storage hopper. All conveyors exposed to the elements are covered; conveyors which run above-grade are provided with access platforms and ramps. The screened residue conveyor is

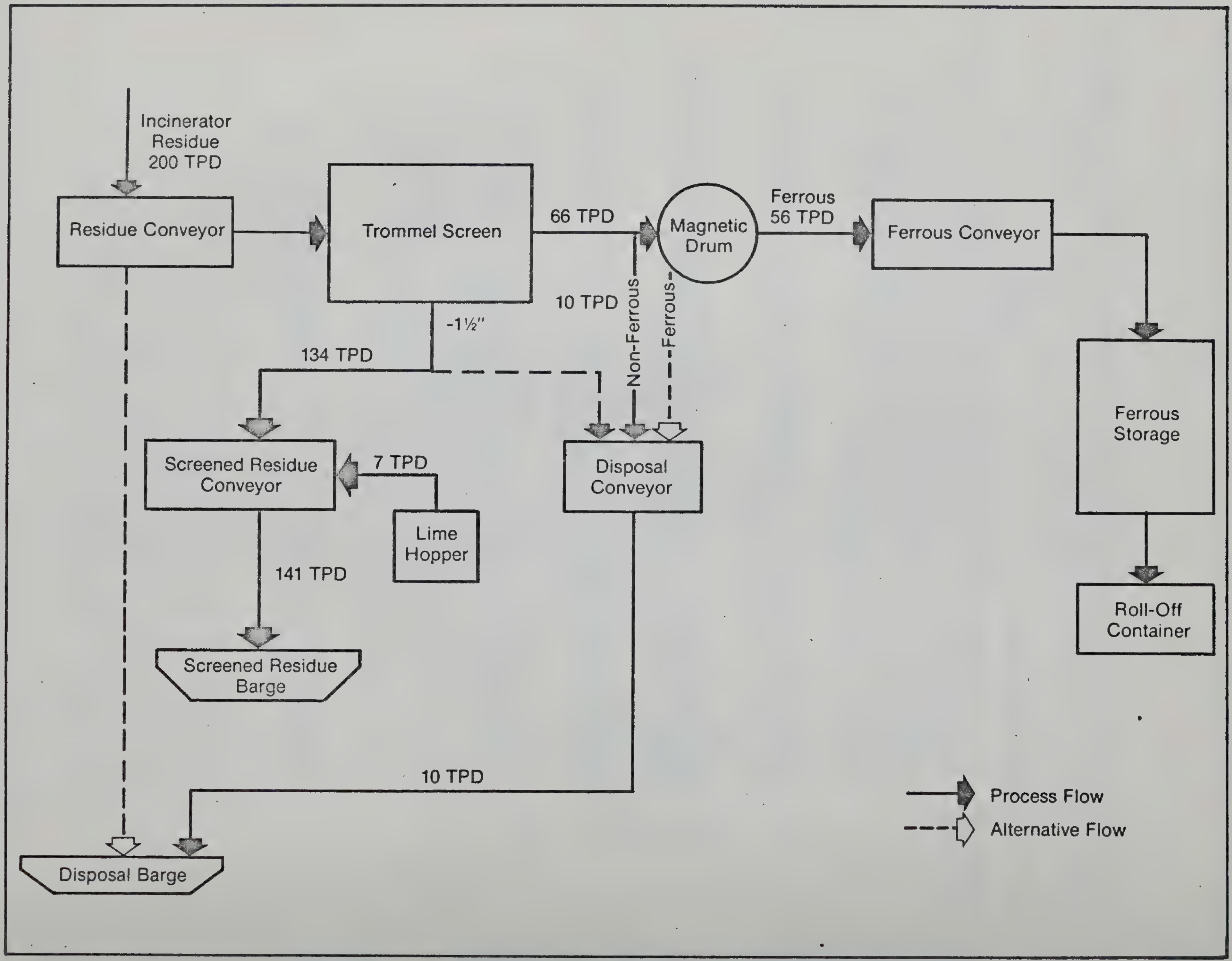


FIGURE 7-4 ALTERNATIVE 3: FERROUS & AGGREGATE RECOVERY

equipped with a travelling discharge spout to allow longitudinal loading of the residue barge.

8. Conveyor supports -- Provided to elevate appropriate sections of the conveyor system. The supports consist of steel bents, as required to support the weight of the conveyor and residue fractions.

9. Slide gates -- Include electrically-operated slide doors to open and close the bottom of the existing barge conveyors. In the open position, residue falls to the new belt conveyor and is transported to the materials recovery building. When closed, the recovery process is bypassed.

10. Lime addition equipment -- Supplied on alternatives incorporating screened residue recovery. This equipment consists of a lime storage hopper and feeder which serves to meter a predetermined quantity of lime into the screened residue prior to storage in the residue barge. An estimated two-day supply of lime can be stored in the hopper.

11. Enclosure -- A prefabricated steel building complete with operator's office, HVAC, suitable foundations and pilings, garage doors, lighting, and overhead travelling crane will be used to house the trommel and magnetic separator.

12. Dredging and bulkheads -- Includes dredging the existing barge slip south of the incinerator to accommodate barges for screened residue, and to permit refurbishing the existing bulkhead.

7.7.3 Cost Estimates

Cost estimates for Alternatives 1 through 3 are presented in Table 7-4. Annual costs for operation and maintenance, as well as projected revenues, are presented in Section 9.

7.7.4 Total Recovery Concepts

Two concepts were developed which eliminate the need for the existing barge disposal system. In each of these systems, nonferrous materials rejected by the magnetic drum are shredded and

Table 7-4

Partial Recovery Alternatives -- Capital Costs

	Alternative		
	1	2	3
Item	Ferrous	Aggregate	Ferrous and Aggregate
Trommel screen	$ 55,000	$ 55,000	$ 55,000
Bifurcated hopper	--	--	5,000
Delivery chutes	12,500	12,500	15,000
Magnetic separator	35,000	--	35,000
Ferrous storage hopper	50,000	--	50,000
Reject chute	2,500	2,500	2,500
Belt conveyors	125,000	200,000	221,000
Conveyor supports	20,000	30,000	40,000
Slide gates	15,000	15,000	15,000
Lime addition equipment	--	45,000	45,000
Enclosure	32,000	29,000	32,000
Foundation	6,000	6,000	6,000
Site work	76,000	76,000	76,000
Assembly and materials	4,000	4,000	4,000
Dredging and bulkheads	--	62,000	62,000
	$433,000	$537,000	$663,500
Electrical at 15%	65,000	81,000	100,000
Instrumentation at 5%	22,000	27,000	33,000
Total Equipment Costs	$520,000	$645,000	$796,500

returned to the incinerator. The shredding process reduces the trommel oversize materials so that they pass through the screen on the next pass. In addition, large combustibles are reduced in size and thus, are more easily burned in the incinerator. A typical site layout for these concepts is illustrated on Figure 7-5.

7.7.4.1 Alternative 4 -- Total Recovery with Ferrous Materials Sale.

This concept is similar to Alternative 3, with the addition of the nonferrous shredder and recycling system just described. Ferrous materials separated by the magnetic drum are stored prior to marketing; screened residue (trommel undersize) is mixed with lime and stored in the screened residue barge. Figure 7-6 illustrates this process.

7.7.4.2 Alternative 5 -- Total Recovery with Optional Ferrous Materials Sale.

This alternative is identical to Alternative 4, with the addition of a ferrous shredder. This offers the option of adding shredded ferrous materials to the screened residue to increase aggregate output. This process is illustrated on Figure 7-7.

7.7.5 Major Equipment

Descriptions of major components are identical to those presented in subsection 7.7.2, with the following additions:

1. Nonferrous conveyor -- Transports rejects from the magnetic drum to the new shredder located adjacent to the receiving pit. Nonferrous materials are shredded to <1 1/2-inch and redeposited in the refuse pit for reincineration.

2. Nonferrous shredder -- Provided to reduce the oversize nonferrous materials from the trommel screen. This unit consists of a hammermill designed to reduce the material size to <1 1/2-inch.

3. Ferrous shredder and enclosure -- Used to reduce the ferrous materials in the residue to <1 1/2-inch for incorporation into the screened residue for resale. The entire assembly will be housed in an extension to the enclosure for the trommel and magnetic drum.

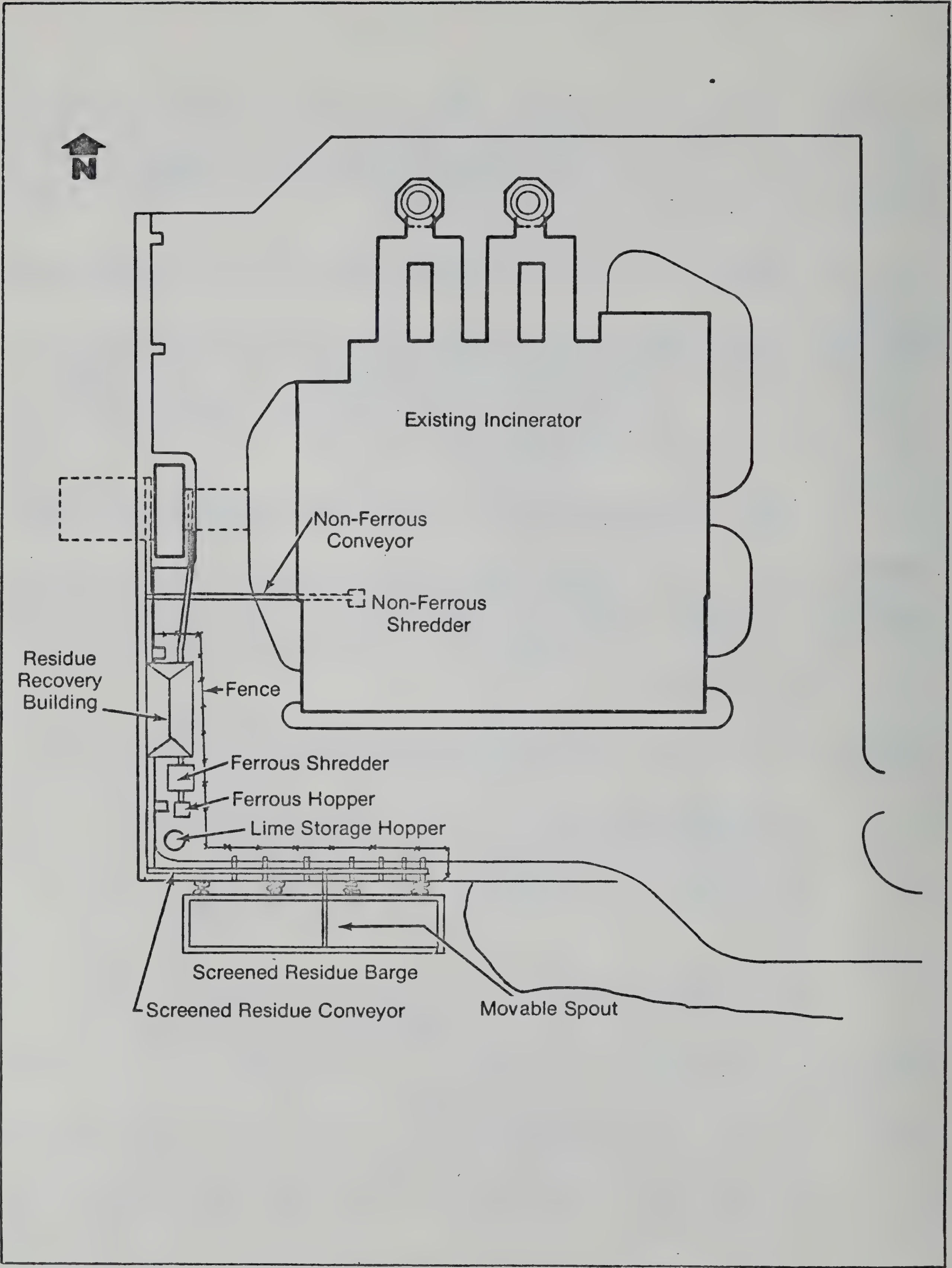


FIGURE 7-5 SITE LAYOUT TOTAL RECOVERY OPTIONS

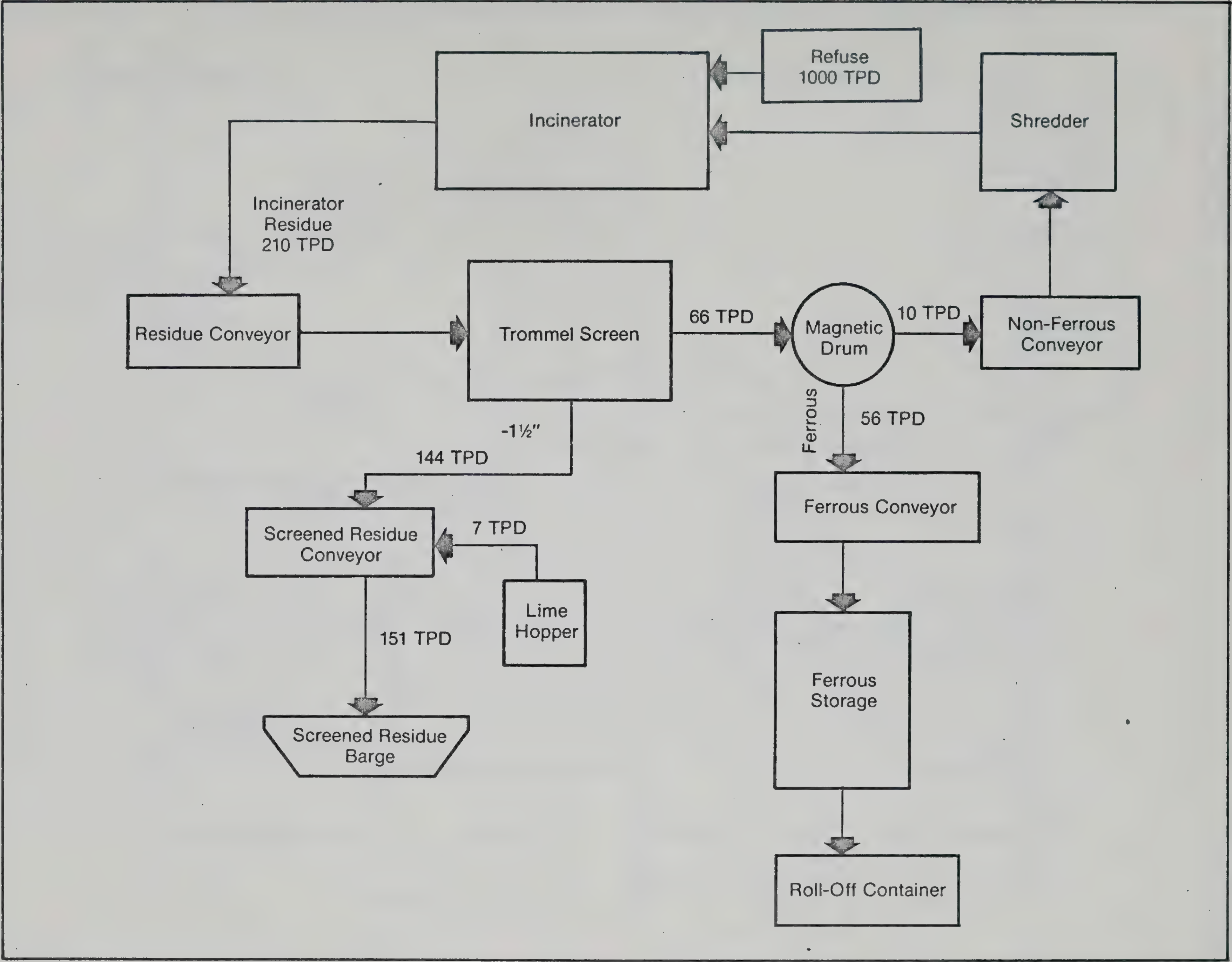


FIGURE 7-6 ALTERNATIVE 4: TOTAL RECOVERY WITH FERROUS SALE

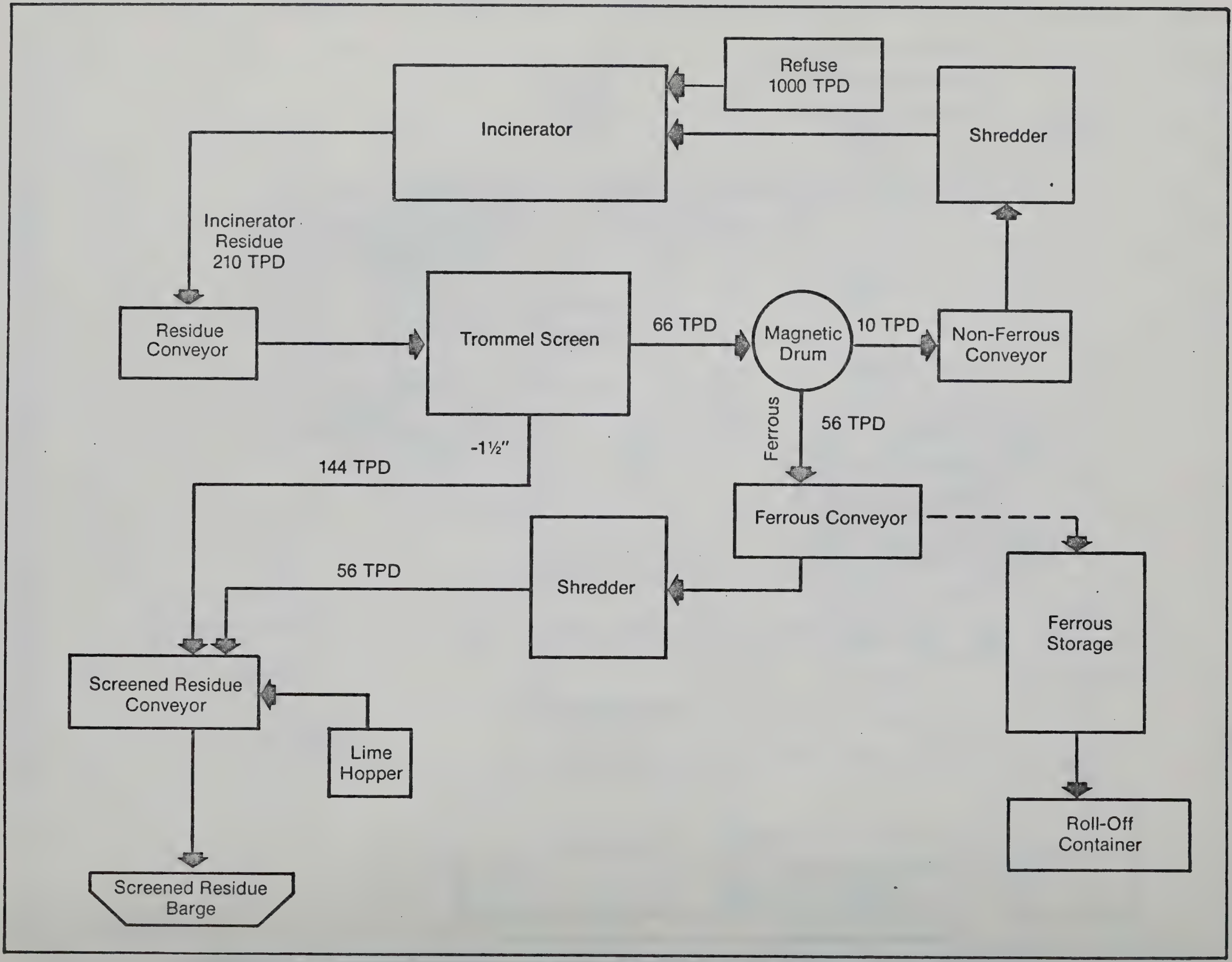


FIGURE 7-7 ALTERNATIVE 5: TOTAL RECOVERY WITH OPTIONAL FERROUS SALE

7.7.6 Cost Estimates

Capital cost estimates for Alternatives 4 and 5 are presented in Table 7-5. Operating costs and revenues are discussed in Section 9.

Table 7-5

Total Recovery Alternatives -- Capital Costs

Item	Alternative 4 Ferrous Resale with Residue Aggregate	 5 Ferrous Resale or Total Aggregate
Equipment cost estimate (Alternative 3)	$663,500	$663,500
Nonferrous conveyor	25,000	25,000
Nonferrous shredder	25,000	25,000
Ferrous shredder and enclosure	--	75,000
	$713,500	$788,500
Electrical at 15%	107,000	118,000
Instrumentation at 5%	36,000	39,000
Total Equipment Costs	$856,500	$945,500

SECTION 8

FURNACE NO. 1 AIR POLLUTION ABATEMENT RECOMMENDATIONS

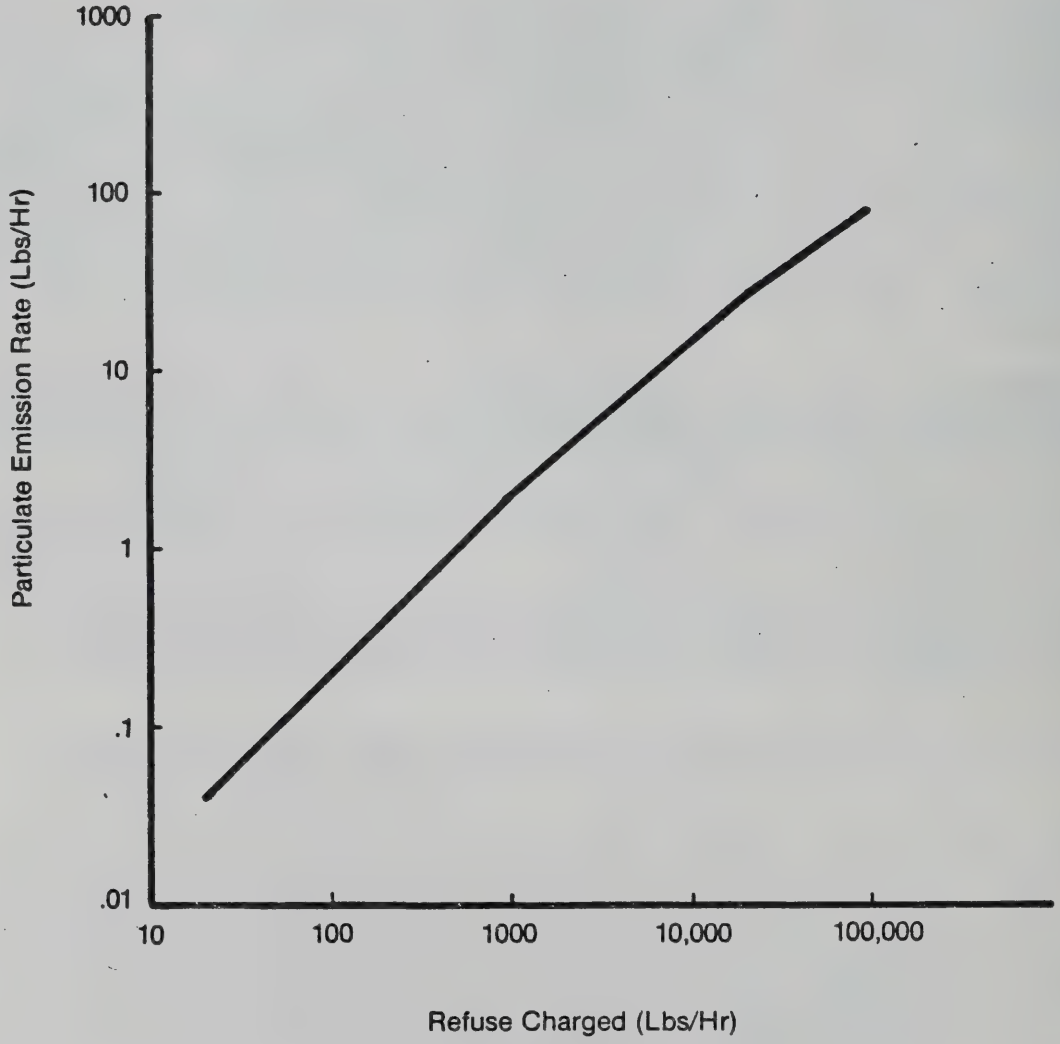
8.1 BACKGROUND

Emission of particulate matter from the incineration of municipal solid wastes in New York State is regulated by Part 222 of the NYSDEC Official Compilation of Codes, Rules and Regulations. According to Part 219 of the Code, the combustion of refuse for the purpose of energy recovery is also regarded as an incineration process and is subject to identical emission standards. Allowable emission limits for particulate matter emanating from refuse incinerators are presented on Figure 8-1. Based on a refuse processing rate of 1,000 tpd, the permissible particulate emissions limit at the Southwest Brooklyn Incinerator is 45 lbs/hr/stack.

In the early 1970's, several methods of controlling incinerator plant stack emissions were proposed to the City of New York by various equipment suppliers. These methods included:

1. A high energy wet scrubber (Chemical Construction Corp.).
2. An upflow gas-conditioning tower coupled with an electrostatic precipitator (Research Cottrell Corp.).
3. A downflow gas-conditioning tower coupled with an electrostatic precipitator (Wheelabrator Corp.).

Three incinerator plant locations were selected by the City of New York for testing the proposed technologies: Southwest Brooklyn, South Shore, and East 73rd Street. One furnace train at each facility was equipped with one of the aforementioned abatement methods by the respective equipment manufacturer. Of the three methods, the downflow gas-conditioning tower and electrostatic precipitator, installed at the Southwest Brooklyn Incinerator Plant, proved the most successful in terms of operation, equipment life, and emission abatement efficiency. Operation of this equipment reduced particulate emission rates from 100 lbs/hr down to approximately 7 lbs/hr, for an average collection efficiency of 93.5 percent.



Source: 6NYCRR Part 219.

FIGURE 8-1 PERMISSIBLE PARTICLE EMISSIONS FROM INCINERATORS

Several independent engineering studies were performed using the operating history and subsequent emission test results from the Southwest Brooklyn Incinerator Plant furnace train prototype. Engineering and redesign was performed on the remaining three furnace trains at this facility, as well as the remaining five incinerator plants. The engineering and redesign was completed incorporating the downflow gas-conditioning tower, and a two-field electrostatic precipitator.

Due to excessive construction costs associated with some of the redesign concepts, only three of the incinerator plants were rehabilitated: Southwest Brooklyn, Greenpoint, and Betts Avenue. At this time, the equipment at all three plants is in various stages of completion.

8.2 PRESENT STATUS

At the Southwest Brooklyn Incinerator facility, furnace No. 1 is still equipped with the original prototype system, the downflow tower design. This equipment has not been operational for some time, and a review of the installation, coupled with discussions with plant operating personnel, indicates that a complete electrostatic precipitator replacement is required while much of the refractory in the uptake flue gas breeching and the gas-conditioning tower itself is in need of replacement. A visual inspection of the electrostatic precipitator, in the areas where the insulation and casing are missing, indicates severe corrosion resulting from dew-point acid attack. Similar corrosion is evident on the gas-conditioning tower and the induced-draft fan.

The downflow flue gas-conditioning system, presently installed but inoperative on furnace No. 1, is connected to the top of the existing separation chamber. The flue is lined with firebrick and rises approximately 85 feet above grade and enters the top of the gas-conditioning tower. The system was designed to handle 169,500 CFM of flue gas at 1,210° F. The gas-conditioning tower has a 9-inch thick castable refractory liner over the upper 20 feet of straight shell height, and a 4 1/2-inch thick acid resistant brick over the remainder of the tower. A group of spray nozzles is located in the transition section between the flue and the gas-conditioning tower entrance. These nozzles are of the manufacturer's proprietary design, and operate on a back-pressure system with modulating control.

The spray water supply pumps are designed to deliver 150 gpm at 650 psi. The conditioned flue gas exits from the lower side of the gas-conditioning tower into a metal breeching and turns up into a distribution section located at the electrostatic precipitator inlet.

The overall size of the electrostatic precipitator is 20 feet-8 inches long by 23 feet 2 inches wide. The flow velocity is approximately 4 ft/sec, resulting in a retention time of 5.4 seconds. The retention time in the gas-conditioning tower, over the active height of 42 feet, is approximately 4.25 seconds.

The electrostatic precipitator shell construction consists of 3/16-inch mill steel with structural stiffeners. The gas-conditioning tower shell is 1/2-inch and 3/8-inch boiler plate over the 9-inch and 4 1/2-inch refractory linings, respectively.

The new air pollution control systems, installed on furnaces nos. 2, 3, and 4, as proposed under Project S-157,(23) are comprised of the following equipment:

1. Gas-Conditioning Tower.

   The gas-conditioning tower is designed to handle 154,300 ACFM of unconditioned furnace flue gases at an approximate temperature of 1,420°F. The gas-conditioning tower is completely refractory lined as described in the paragraphs that follow.

   The downflow concept gas-conditioning tower necessitated the installation of an 8-foot inside diameter, vertical, refractory-lined gas passage located at the flue gas discharge end of the existing furnace. The gas passage extends upward through the existing building roof. At the high point, the gas passage turns down, reversing the gas flow. The gas passage then enters a 16-foot inside diameter refractory-lined gas-conditioning tower through an integral refractory-lined transition piece which houses the gas-conditioning water spray nozzles.

The conditioned flue gases leave the gas-conditioning tower approximately 20 feet above grade. The bottom of the gas-conditioning tower is equipped with ash discharge valves to hold the air seal, and a horizontal drag-flight conveyor to transport the deposited fly ash to the main collection conveyor.

2. Electrostatic Precipitators.

Two-field electrostatic precipitators were provided with overall plan dimensions of approximately 21 feet by 13 feet. Each field is approximately 9 feet long, arranged in series. The shell is 3/16-inch Corten, gas-tight, unitized, welded construction. The electrostatic precipitators were designed for a water gauge pressure of 20 inches positive or negative, a working stress of 20,000 psi maximum, and a maximum operating temperature of 650°F. The electrostatic precipitators handle approximately 105,600 ACFM of conditioned flue gases at an average temperature of 550°F.

3. Induced-Draft Fans.

The induced-draft fans were designed to handle 105,600 ACFM, plus "test-block" allowances at 550°F, and a static pressure of 6-inches water gauge as determined by the final design arrangement. The induced-draft fan draws the conditioned flue gases from the electrostatic precipitator and discharges them into the stack.

4. Water Booster Pumps.

Individual water booster pumping systems were provided for the gas-conditioning tower. These pumps supply cooling water to the unconditioned furnace flue gases. Each system consists of one pump and one spare pump, each designed to supply 100 gpm at 300-psi pressure at the spray nozzles, including the necessary valving, solenoid valves, etc.

5. Insulation.

Insulation was provided for the entire electrostatic precipitator, all breeching, induced-draft fan, ash conveyors, and exposed water and air piping.

6. Breeching.

Interconnecting breeching was provided between the gas-conditioning tower and the electrostatic precipitator, including the necessary access doors, test openings, turning baffles, etc; between the electrostatic precipitator and the induced-draft fan, including the test opening, turning baffles, etc; and between the induced-draft fan and the existing stack. The breeching was designed to withstand the positive and negative pressures and temperature stresses in the system, and includes expansion joints as required.

7. Fly Ash Removal.

The fly ash collected in the gas-conditioning tower is removed using a horizontal drag-flight conveyor. The electrostatic precipitators are also emptied through a drag-flight conveyor. These individual conveyors discharge into a centrally-located conveyor system. This system of drag-flight conveyors penetrates the existing building wall at one location and deposits the collected fly ash into one of two existing furnace residue conveyors. This design provides operating flexibility in the event of mechanical failure. All fly ash removal conveyors located outside the incinerator plant building are totally enclosed, insulated, and electrically-traced so that the fly ash will not freeze. The minimum drag-flight conveyor width is 12 inches.

The two major control systems proposed under Project S-157 were:

1. Gas Temperature Control System.

   The control of the gas temperature at the electrostatic precipitator is maintained by varying the number of solenoid-controlled water spray nozzles in operation. The temperature-sensing device consists of parallel thermocouples located at the inlet breeching to the induced-draft fan. Parallel thermocouples are provided to protect the system against shutdown due to the failure of one thermocouple. Loss of temperature signal automatically drives the system to maximum cooling.

2. Furnace Draft Control System.

   The removal of combustion products from the furnace is controlled by variable speed operation of the induced-draft fan. Control signals representative of furnace draft and motor current are monitored by a signal-selected unit to maintain furnace draft at the desired set point under all conditions that do not involve a motor overload. The motor current overload protection is provided to prevent shutdown of the system if cold gas overloads the fan during start-up and shut-down operations. Motor speed and draft indicators are provided.

8.3 CONCEPT DESIGN

Based on a review of air pollution control requirements and the deteriorated condition of the existing equipment, it is recommended that the existing air pollution control equipment, including the downflow gas-conditioning tower, single-field electrostatic precipitator, induced-draft fan and drive, breeching and ductwork, and associated spray water pumps and piping associated with furnace No. 1, be demolished and removed. In place of this equipment, a new system, similar in design to the remaining three furnaces, should be installed. This equipment would include:

1. A downflow gas-conditioning tower and associated breeching and possible external insulation.

2. A two-field electrostatic precipitator externally insulated and clad.

3. An induced-draft fan and drive (capable of handling waste heat boiler pressure differential).

4. Modified waste heat bypass dampers.

5. A control system compatible with the remaining three furnace trains.

A site plan of this equipment is illustrated on Figure 8-2.

While it is possible that the gas-conditioning tower and refractory-lined uptake flue could be eliminated due to the incorporation of the waste heat boiler, the gas-conditioning tower is still an alternate flue gas path and will allow refuse incineration while the waste heat boiler is out of service. In addition, the entire resource recovery portion of this feasibility study is conceptual at this writing. If the waste heat boilers are not installed, flue gas cooling on furnace No. 1 could not be accomplished without the inclusion of the gas-contioning tower.

Normal operation involving incineration and resource recovery through the waste heat boiler will remove considerable moisture from the flue gas stream. This could adversely affect the particulate collection in the electrostatic precipitator. Conversations with manufacturers of electrostatic precipitators indicate that they do not feel that the equipment will be adversely affected due to the design parameters originally employed. Furthermore, should the "dry" flue gas affect the collection efficiency, one or more of the individual gas-conditioning tower water sprays could be operated to add the required moisture. This method of operation will lower the temperature of the flue gas but, due to the additional insulation specified between the waste heat boiler outlet and the electrostatic precipitator inlet, neither the power generation rate nor the electrostatic precipitator collection efficiency will be affected.

8.3.1 Major Equipment

To accomplish the recommended concept work, the following work items and their associated costs are presented:

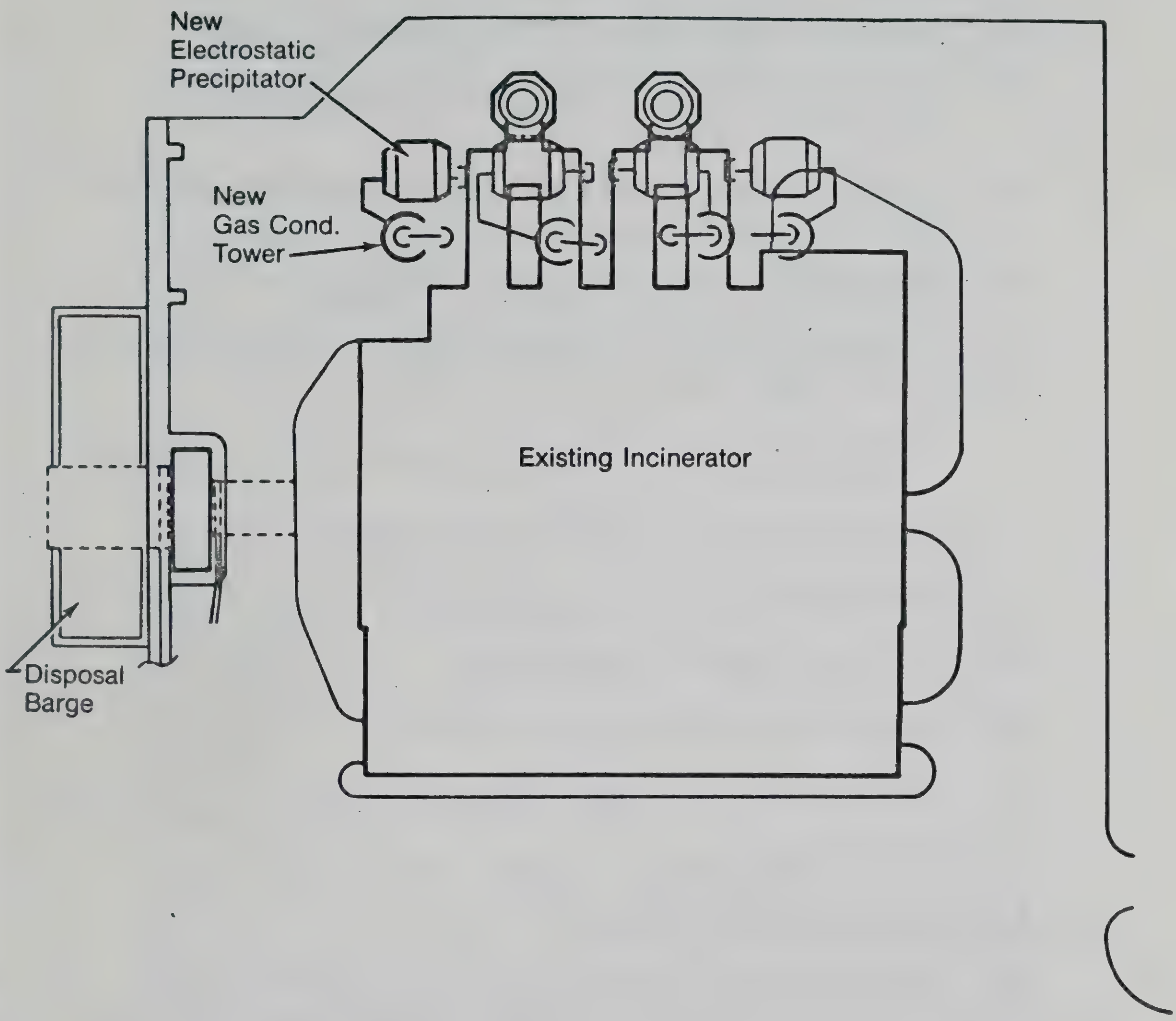


FIGURE 8-2 APC EQUIPMENT ARRANGEMENT

1. Demolition.

   Demolition includes the removal of:

   a. Existing refractory-lined uptake flue.

   b. Refractory-lined steel-shell gas-conditioning tower.

   c. Single-field insulated electrostatic precipitator.

   d. Interconnecting breeching between:

      - Gas-conditioning tower and the electrostatic precipitator.

      - Electrostatic precipitator and the induced-draft fan.

      - Induced-draft fan to the stack.

   e. Induced-draft fan and drive.

   f. Fly ash removal conveyors.

   g. Water spray pumps and drives.

   h. Access platforms and stairs.

   i. Foundations.

2. Excavation and Backfill.

   This includes the work required to install the necessary foundations and pile caps for the loads imposed by the new equipment.

3. Piles and Foundations.

   This item includes the material and labor required to install the supports for the structural superstructure.

4. Paving.

   Paving includes the restoration of existing pavements for truck access.

5. Structural Steel.

This item includes superstructure similar to that supporting the air pollution control equipment associated with furnace trains Nos. 2, 3, and 4. It includes the concrete pad for the induced-draft fan, intermediate grating platforms, and interconnecting stair towers.

6. Uptake Flue.

The uptake flue includes approximately 100 linear feet of 8-foot inside diameter refractory breeching. It includes the necessary refractory lining, transition sections from the secondary combustion chamber and from the flue to the gas-conditioning tower, and all elbows.

7. Gas-Conditioning Tower.

The downflow gas-conditioning tower designed to handle approximately 154,300 SCFM of unconditioned gases at 1,420°F, will be approximately 16 feet inside diameter and equipped with an air-assisted water spray system capable of reducing the gas temperature to 550°F. (See Table 6-1 for a discussion of design and operational difficulties.)

8. Electrostatic Precipitator.

A two-field electrostatic precipitator, consistent with those already in service, should be provided capable of handling 105,600 SCFM of conditioned flue gases at a minimum temperature of 400°F. The electrostatic precipitator must be capable of collecting sufficient fly ash particulates to limit emissions to 0.2 grains/SCFM, corrected to 12 percent CO_2 at normal combustion rates.

9. Induced-Draft Fan and Drive.

The induced-draft fan will be sized to handle 175,000 CFM at 550°F and 0.35 lbs/cu ft density. This fan will have identical characteristics to the three existing induced-draft fans. The system will incorporate the additional pressure drop encountered as a result of the proposed waste heat boiler. Based on the waste heat boiler selected, the total system pressure drop will be in the 8- to 12-inch negative water column range which will increase the size of the variable speed drive motor to approximately 350 hp.

10. Breeching.

The breeching connecting the gas-conditioning tower to the electrostatic precipitator and the electrostatic precipitator to the existing stack entrance will be plain carbon steel shell. The breeching between the tower and the precipitator will be externally insulated and covered with an aluminum jacket.

11. Dampers.

The dampers will be of the butterfly valve-type with an elastomeric covering molded to the metal disc and housing. The dampers will be equipped with air or electric activators for full-open or closed positioning.

12. Spray Water System.

A temperature control system consisting of an air compressor, water booster pump nozzles, and piping will be supplied. The system will be similar to the systems presently installed on furnaces Nos. 2, 3, and 4. The air compressor will control the water droplet size, thereby enhancing evaporation and reducing moisture carryover into the electrostatic precipitators.

13. Fly Ash Conveyors.

Drag-flight-type conveyors will be provided to transport collected fly ash from both the gas-conditioning tower and the electrostatic precipitator. These conveyors will be connected to and integrated with the existing system.

8.4 CAPITAL COST ESTIMATES

Capital cost estimates for the air pollution control equipment on furnace No. 1 are summarized in Table 8-1. Equipment costs with design, engineering and construction management, and contingencies are presented in Section 9.

Table 8-1

Capital Cost Estimate -- Air Pollution Control Equipment for Furnace No. 1

Item	Cost
Demolition	$ 107,500
Excavation and backfill	5,000
Pilings and foundation	249,300
Paving	5,400
Structural steel	123,900
Uptake flue	230,000
Gas-conditioning tower	300,000
Electrostatic precipitator	600,000
Induced-draft fan and drive	244,500
Breeching	120,000
Dampers	288,000
Air compressor and piping	25,000
Water pumps and piping	39,500
Fly ash conveyors	112,500
	$2,450,600
Electrical at 30%	735,200
Instrumentation at 10%	245,100
Installation of gas-conditioning tower, electrostatic precipitator, and induced-draft fan	293,500
Total Equipment Cost	$3,724,400

SECTION 9

COST EVALUATION

9.1 INTRODUCTION

The total costs and revenues associated with each energy and material recovery alternative discussed in Sections 6 and 7, respectively, and the costs for air pollution abatement requirements discussed in Section 8, are presented in this section.

The total capital costs for each of the three energy recovery alternatives were estimated based on PASNY economic criteria (presented in Appendix H) and include:

1. Installed equipment costs.
2. Spare parts.
3. Licensing.
4. Design, engineering, and construction management.
5. Contingency.

Total bond issue requirements were developed for each energy recovery alternative based on the project schedule presented in Figure 9-1, and include:

1. Debt service coverage.

2. Bond reserve.

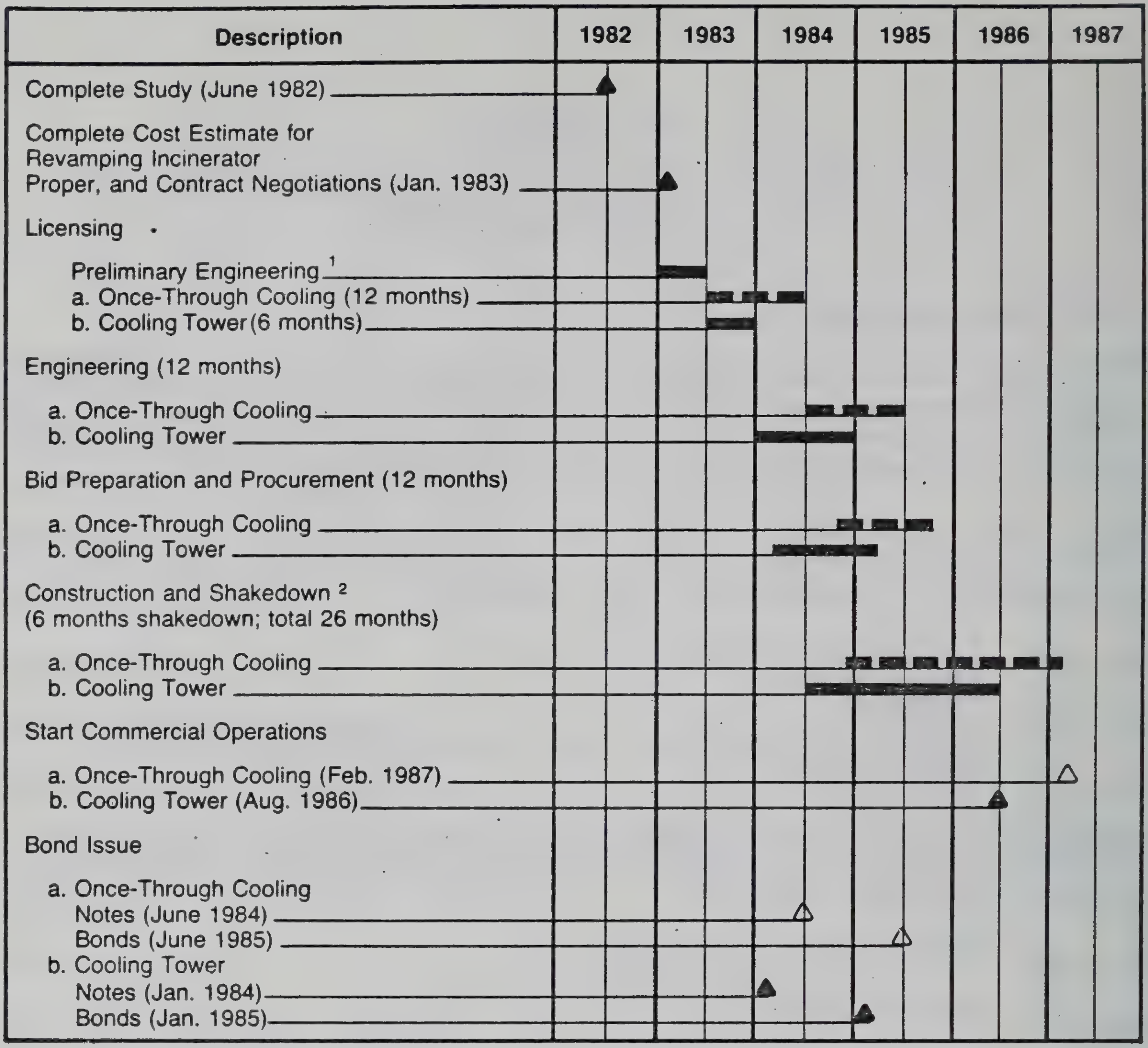
3. Bond financing costs.

4. Capitalization of operation and maintenance costs incurred during start-up.

The annual costs and revenues for each energy recovery alternative were developed utilizing PASNY criteria for electricity and steam rates, escalation, interest rates, and utility costs for make-up water.

The material recovery capital costs presented in this section include:

1. Installed equipment costs.
2. Design, engineering, and construction management
3. Contingency.



1. Preliminary outline drawings and budget prices of main equipment (e.g., boiler and turbine/generator) will be requested from potential suppliers.

2. Based on the following time estimate for the necessary activities:
   a. Equipment specifications -- 2 months
   b. Bid preparation -- 2 months
   c. Contract awarding -- 1 month
   d. Boiler delivery -- 12 months
   e. Boiler erection (in pairs) -- 4 months
   f. Boiler startup -- 6 months
   g. Turbo-generator delivery -- 16 months
   h. Turbo-generator erection -- 6 months
   i. Turbo-generator startup -- 4 months
   Critical path -- 31 months

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FIGURE 9-1 PROJECT SCHEDULE

The financing costs for implementation of these alternatives were not included in this analysis. In addition, annual costs and revenues have not been adjusted for escalation over the life of the facility.

The total costs for construction of air pollution equipment on furnace No. 1 have been developed, and include:

1. Installed equipment costs.
2. Design, engineering, and construction management.
3. Contingency.

No additional financing costs were developed for the air pollution control equipment.

9.2 ENERGY RECOVERY ALTERNATIVES

A detailed economic evaluation was performed on the three energy recovery alternatives presented in Section 6. The total capital costs for each alternative consist of:

1. Direct costs.
2. Indirect costs.
3. Contingency.

Each of these components was calculated using PASNY economic criteria. The costs for the three alternatives are presented in Table 9-1.

9.2.1 Direct Costs

The direct costs for each alternative include:

1. Installed equipment costs.
2. Spare parts.
3. Licensing.

The installed capital costs for each alternative are as follows:

1. Electricity Only.

   This cost includes waste heat boilers, turbine generating equipment, and the ancillary equipment listed in Table 6-5.

   Installed equipment costs = $26,972,000

Table 9-1

Total Capital Costs and Bond Issues

Item	Electricity Only $1,000	Cogeneration -- Full Steam Loop $1,000	Cogeneration -- Partial Steam Loop $1,000
Direct Costs			
Installed equipment	$26,972	$ 53,082	$32,309
Spare parts (at 4 %)	1,079	2,123	1,292
Licensing	250	250	250
Total Direct Costs	$28,301	$ 55,455	$33,851
Indirect Costs			
Design, engineering, and construction management at 15%	$ 4,245	$ 8,318	$ 5,078
Subtotal	$32,546	$ 63,774	$38,929
Contingency at 15%	4,882	9,566	5,839
Total Capital Costs (1981)	$37,428	$ 73,340	$44,768
Total Inflated Costs (1982)	$41,171	$ 80,674	$49,240
Total Bond Issue I (Dec. 1984)	$66,995	$130,583	$79,981
Total Bond Issue II (1998)	$ 8,525	$ 8,525	$ 8,525

2. Cogeneration -- Full Steam Loop.

This concept incorporates the steam generating equipment utilized for generation of electricity and adds an extraction capability for the purpose of supplying thermal energy to a district heating network. Installed equipment costs for this alternative are summarized as follows:

Waste heat boilers and generation equipment (Table 6-6)	$27,627,000
District heating network (Table 5-6)	25,455,000
Total	$53,082,000

3. Cogeneration -- Partial Steam Loop.

This alternative utilizes part of the steam generated by the combustion of refuse for distribution in a smaller district heating network. The total equipment costs are summarized as follows:

Waste heat boilers and generating equipment (Table 6-6)	$27,487,000
District heating network (Table 5-5)	4,822,000
Total	$32,309,000

Spare parts for the first year of operation are estimated at 5 percent of the installed equipment cost.

9.2.2 Indirect Costs

Indirect costs include:

1. Design, engineering, and construction management.
2. Licensing.

Design, engineering, and construction management costs are 15 percent of the total direct costs listed. Licensing and permit costs have been estimated at $250,000.

9.2.3 Total Capital Costs and Bond Issue

A contingency of 15 percent was added to all direct and indirect costs to develop the total capital costs presented in Table 9-1.

The modifications to the incinerator will be financed with bonds issued for 27.5 years at 10 percent interest starting in 1984. This assumes a 2.5-year bid and construction period, and a 25-year facility life. The costs associated with this bond issue are:

1. Debt service coverage.
2. Bond reserve requirement.
3. Bond financing costs.
4. Interest during construction.
5. Capitalization of start-up operation.

Debt service coverage was established at 15 percent above total debt service. The bond reserve requirement is one year's interest of the total bond issue, reinvested at an annual interest rate of 11.5 percent. The bond financing costs are 2 percent of the total bond issue. Estimated operation, maintenance, and interest costs to be incurred during plant start-up are capitalized into the total bond issue. The total estimated operation and maintenance required for start-up and shakedown for each alternative were estimated at 3.5 percent of the total capital costs.

Total capital costs for each alternative, in 1981 dollars, were inflated to the time of construction (1984) using an annual inflation rate of 10 percent. The total bond costs were developed using computer programs supplied by PASNY (Revised Bond Issue Program). Outputs from these programs for each alternative are presented in Appendix I, and summarized in Table 9-1. The 1998 bond issue presented in Table 9-1 represents a new issue to cover the costs of the installation of new boilers. Further discussion of this new installation is presented in subsection 9.2.6.

9.2.4 Operation and Maintenance Costs

Operation and maintenance costs include the labor costs associated with operating the steam plant and waste heat boiler, the make-up water costs associated with the cooling towers and waste heat boiler blowdown, maintenance, insurance, general and administrative expenses, and contingency. The operation and maintenance costs developed are utilized to calculate cash flow (subsection 9.2.5).

The labor costs are based on the number of personnel required to operate and maintain the plant. The estimated labor force (excluding the existing plant operation and maintenance personnel) is shown in Table 9-2. The estimated average 1981 labor rate is $30,000 per person per year, and escalates at 8 percent per year. The labor costs presented in Table 9-2 are based on a four-shift operation.

The maintenance labor force is based on normal maintenance requirements and operation. Extra labor would be needed for major repairs and overhauls and equipment modifications. It is assumed that extra labor would be contracted as required.

The make-up water costs are based on the net make-up water requirement for each of the alternatives. The net make-up water requirement includes the make-up for the cooling towers, steam cycle, and district steam system, less the reduced water usage for the gas-conditioning towers, which would not be in operation under normal operating conditions. The make-up water cost is $1.50/1,000 gallons in 1981, and escalates at 8 percent per year.

Included for maintenance costs is 1.8 percent of the total capital cost, such as spare and repair parts, annual chemical costs for steam cycle treatment and circulating water treatment, and miscellaneous overhaul and replacement requirements. This estimate escalates at 8 percent per year and is an average value based on previous estimates for a power plant of about 20 MW. It does not include routine incinerator maintenance or grate replacement costs since these expenses will be incurred even if the proposed modifications are not made. It is anticipated, however, that incinerator maintenance will decrease since the operation will be continuous. The incinerators will not be subjected to the thermal stresses of weekly start-ups and shutdowns as is now the case.

Insurance is estimated at 0.25 percent of the capital cost; and general and administrative expenses are 5 percent of the total payroll, utilities, maintenance, and insurance costs.

The power cost associated with the operation of the plant auxiliaries is not included as an operating cost since the total generating capacity and steam revenues already are based on net generating values. The auxiliary power requirement is subtracted from the gross capacity prior to calculating the revenues in subsection 9.2.5.

Table 9-2

Operating and Maintenance Labor (Energy Recovery)[1]

Category	People
Plant Superintendent	1
Plant Clerk	1
Foreman -- Shift	4
Control Room Operators	8
Utility Operators	4
Maintenance Personnel	4
Electrician	1
Total	23

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[1] Assumes four-shift operation; plant is to be operated 7 days/week, 24 hours/day.

A listing of the operating costs for 1981, shown in Table 9-3, provides the basis for future escalated operation and maintenance costs, utilized for analyzing cash flow, as discussed in subsection 9.2.6.

9.2.5 Projected Revenue Criteria

Estimates of electrical generation capacity were developed based on the energy availability model discussed in Section 4. The total electricity generated for revenue calculations is presented in Table 9-4. Projected revenues are based on the economic criteria presented in Appendix H, and the project schedule presented in Figure 9-1.

Projected revenues for each alternative were developed using New York State Power Pool rates for electricity, and either a direct oil replacement rate (0.3 percent sulfur) or on a rate based on oil costs that included the operational cost of the cogeneration portion of the facility. The derivation of these rate structures is presented in Appendix J.

Using the varying rate structures, five projected revenue streams were generated, as follows:

- 1A Electricity only (New York State Power Pool).
- 2A Partial steam loop (New York State Power Pool) + (oil replacement).
- 2B Partial steam loop (New York State Power Pool) + (oil and O&M rate).
- 3A Full steam loop (New York State Power Pool) + (oil replacement).
- 3B Full steam loop (New York State Power Pool) + (oil and O&M rate).

Revenues for both cogeneration alternatives are based on the assumption that periods of high steam demand will occur when all of the waste heat boilers are operating. Therefore, it is assumed that the steam demand (up to the maximum steam generation rate of the waste heat boilers) can be supplied whenever needed. Also, for the purposes of this study, it has been assumed that construction of either steam transmission and distribution network will be completed concurrently with the construction of the generating equipment. Numerous other approaches can be used but

Table 9-3

Estimated O&M Costs for Energy Recovery Portion of Facility
(Third quarter 1981 dollars)

Cost Element	Annual Cost		
	Electricity Only	Full Steam	Partial Steam
Payroll (23 x $30,000)	$690,000	$690,000	$690,000
Utilities	10,000	(40,000)[1]	(13,000)[1]
Maintenance (1.8 percent of capital cost)	485,000	955,000	582,000
Insurance (0.25 percent of capital cost)	70,000	133,000	81,000
Subtotal	$1,255,000	$1,738,000	$1,340,000
G&A expenses (5 percent)	$ 65,000	87,000	67,000
Subtotal	$1,330,000	$1,825,000	$1,400,000
Contingency fund (15 percent)	200,000	275,000	210,000
Total	$1,530,000	$2,100,000	$1,600,000

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[1] Figures in parentheses represent savings due to not operating the gas conditioning tower sprays, and reduced cooling tower makeup water requirements when heat is rejected to the district heating system evaporator.

Table 9-4

Projected Electricity Generation

Generating Capacity			Net Generating
Gross kW	Net[1] kW	Hours/Year	Capacity kWh
17,300	15,950	2,540	40,513,000
13,120	11,930	3,330	39,726,900
8,490	7,480	1,660	12,416,800
3,090	3,160	350	1,106,000
		Total	93,762,700

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[1] Net generating capacity is the gross capacity less all incremental auxiliary power required by the waste heat boiler retrofit, turbine generator, and balance of plant equipment.

this method ensures that the district heating alternatives receive the most favorable consideration possible. The steam revenues included in the cash flow forecast are the highest possible revenues attainable. Total quantities of steam generated are presented in Table 9-5.

For each steam alternative, main steam is taken as required to satisfy district heating requirements. The balance is introduced to the turbine for electrical generation. A detailed discussion of the cogeneration operating strategy is presented in subsection 6.3.4. Calculated revenues for each process alternative are presented in the cash flow analyses in subsection 9.2.6.

9.2.6 Cash Flow Forecasts

The cash flow forecasts for the three alternatives are shown in Tables 9-6 through 9-10. These forecasts are based on the capital cost estimates discussed previously and the economic criteria listed in Appendix H. The basis for the debt payment estimates is the Revised Bond Issue Program (Appendix I). The forecasts summarize the escalated annual costs and revenues.

The cash flow projections presented in Tables 9-6 through 9-10 were developed by combining the output of the Revised Bond Issue Program with the projected revenue rate factors previously discussed. In order to facilitate the replacement of the four waste heat boilers, a second bond program was run assuming a 12.5-year service life of the boiler internals (replacement in 1998). It was assumed that replacement of the boiler internals would cost 80 percent of the 1981 capital cost of the boilers, escalated to 1998 at 10 percent per year.

A sixth cash flow for comparison purposes, using electricity rates based on oil replacement costs, is presented in Appendix F.

The operation and maintenance costs are the total costs discussed previously in subsection 9.2.4, and escalated at 8 percent per year.

Electricity and steam revenues are based on the generating capacities listed in subsection 9.2.5.

Table 9-5

Projected District Heating and Electricity Generation

Alternative	Capacity
Full Steam Loop System	
Net generating capacity	43,397,600 kWh/yr
Steam supply	548.0 million lbs/yr
Partial Steam Loop System	
Net generating capacity	71,572,200 kWh/yr
Steam supply	237.5 million lbs/yr

Table 9-6

Cash Flow Forecast -- Electricity Generation Only (1A)
(New York State Power Pool)

Year	Debt Payments $1,000	O&M Costs $1,000	Total Annual Costs $1,000	Electricity Rates $/kWh	Electricity Revenues $1,000	Steam Revenues $1,000	Total Annual Revenues $1,000	Difference in Revenues Minus Cost $1,000
1986	$6,914	$2,222	$9,136	$0.07700	$7,220	0.0	$ 7,220	$ (1,916)
1987	6,914	2,400	9,314	0.08164	7,655	0.0	7,655	(1,659)
1988	6,914	2,592	9,506	0.09537	8,942	0.0	8,942	(564)
1989	6,914	2,799	9,713	0.10482	9,828	0.0	9,828	115
1990	6,914	3,023	9,937	0.11260	10,558	0.0	10,558	621
1991	6,914	3,265	10,179	0.12393	11,620	0.0	11,620	1,441
1992	6,914	3,526	10,440	0.13026	12,214	0.0	12,214	1,773
1993	6,914	3,808	10,722	0.13877	13,011	0.0	13,011	2,289
1994	9,929	4,113	14,042	0.16233	15,220	0.0	15,220	1,179
1995	9,929	4,442	14,371	0.18013	16,889	0.0	16,889	2,519
1996	9,929	4,797	14,726	0.19989	18,742	0.0	18,742	4,016
1997	9,929	5,181	15,110	0.23697	22,219	0.0	22,219	7,109
1998	10,809	5,595	16,404	0.26931	25,251	0.0	25,251	8,847
1999	10,809	6,043	16,852	0.29903	28,038	0.0	28,038	11,186
2000	10,809	6,526	17,335	0.32782	30,737	0.0	30,737	13,402
2001	10,809	7,049	17,858	0.35406	33,198	0.0	33,198	15,340
2002	10,809	7,612	18,421	0.38343	35,951	0.0	35,951	17,530
2003	10,809	8,221	19,030	0.39448	36,988	0.0	36,988	17,957
2004	10,809	8,879	19,688	0.43230	40,534	0.0	40,534	20,845
2005	10,809	9,589	20,398	0.47127	44,188	0.0	44,188	23,789
2006	10,809	10,357	21,166	0.50118	46,992	0.0	46,992	25,826
2007	2,933	11,185	14,118	0.53340	50,013	0.0	50,013	35,895
2008	2,933	12,080	15,013	0.56807	53,264	0.0	53,264	38,251
2009	2,933	13,046	15,979	0.60499	56,725	0.0	56,725	40,746
2010	2,933	14,090	17,023	0.64431	60,412	0.0	60,412	43,389

Table 9-7

Cash Flow Forecast -- Partial Steam Loop (2A)
(New York State Power Pool Electric Rates -- Oil Steam Rates)

Year	Debt Payments $1,000	O&M Costs $1,000	Total Annual Costs $1,000	Electricity Rates $/kWh	Electricity Revenues $1,000	Steam Rates $/1,000 lbs	Steam Revenues $1,000	Total Annual Revenues $1,000	Difference in Revenues Minus Cost $1,000
1986	$ 8,254	$ 2,377	$10,631	$0.07700	$ 5,511	$10.31	$ 2,449	$ 7,960	$(2,671)
1987	8,254	2,567	10,821	0.08164	5,843	11.25	2,672	8,515	(2,306)
1988	8,254	2,773	11,027	0.09537	6,826	12.35	2,933	9,759	(1,268)
1989	8,254	2,994	11,248	0.10482	7,502	13.53	3,213	10,716	(533)
1990	8,254	3,234	11,488	0.11260	8,059	14.79	3,513	11,572	84
1991	8,254	3,493	11,747	0.12393	8,870	16.12	3,829	12,698	952
1992	8,254	3,772	12,026	0.13026	9,323	17.56	4,171	13,493	1,467
1993	8,254	4,074	12,328	0.13877	9,932	19.15	4,548	14,480	2,152
1994	11,853	4,400	16,253	0.16233	11,618	20.87	4,957	16,575	322
1995	11,853	4,752	16,605	0.18013	12,892	22.78	5,410	18,303	1,698
1996	11,853	5,132	16,985	0.19989	14,307	24.75	5,878	20,185	3,200
1997	11,853	5,542	17,395	0.23697	16,960	26.92	6,394	23,354	5,959
1998	12,733	5,986	18,719	0.26931	19,275	29.26	6,949	26,224	7,506
1999	12,733	6,465	19,198	0.29903	21,402	31.80	7,553	28,955	9,757
2000	12,733	6,982	19,715	0.32782	23,463	34.59	8,215	31,678	11,963
2001	12,733	7,540	20,273	0.35406	25,341	37.35	8,871	34,211	13,938
2002	12,733	8,143	20,876	0.38343	27,443	40.34	9,581	37,024	16,147
2003	12,733	8,795	21,528	0.39448	28,234	43.58	10,350	38,584	17,056
2004	12,733	9,499	22,232	0.43230	30,941	47.06	11,177	42,117	19,886
2005	12,733	10,258	22,991	0.47127	33,730	50.82	12,070	45,800	22,808
2006	12,733	11,079	23,812	0.50118	35,871	54.88	13,034	48,905	25,092
2007	2,933	11,965	14,898	0.53340	38,177	59.28	14,079	52,256	37,357
2008	2,933	12,923	15,856	0.56807	40,658	64.02	15,205	55,863	40,007
2009	2,933	13,956	16,889	0.60499	43,300	69.14	16,421	59,721	42,832
2010	2,933	15,073	18,006	0.64431	46,115	74.67	17,734	63,849	45,843

Table 9-8

Cash Flow Forecast -- Partial Steam Loop (2B)
(New York State Power Pool Electric Rates -- Oil and O&M Steam Rates)

Year	Debt Payments $1,000	O&M Costs $1,000	Total Annual Costs $1,000	Electricity Rates $/kWh	Electricity Revenues $1,000	Steam Rates $/1,000 lbs	Steam Revenues $1,000	Total Annual Revenues $1,000	Difference in Revenues Minus Cost $1,000
1986	$ 8,254	$ 2,377	$10,631	$0.07700	$ 5,511	$10.91	$ 2,591	$ 8,102	$(2,529)
1987	8,254	2,567	10,821	0.08164	5,843	11.93	2,833	8,677	(2,145)
1988	8,254	2,773	11,027	0.09537	6,826	13.06	3,102	9,928	(1,099)
1989	8,254	2,994	11,248	0.10482	7,502	14.29	3,394	10,896	(352)
1990	8,254	3,234	11,488	0.11260	8,059	15.60	3,705	11,764	276
1991	8,254	3,493	11,747	0.12393	8,870	17.00	4,038	12,907	1,161
1992	8,254	3,772	12,026	0.13026	9,323	18.52	4,399	13,721	1,695
1993	8,254	4,074	12,328	0.13877	9,932	20.18	4,793	14,725	2,397
1994	11,853	4,400	16,253	0.16233	11,618	21.99	5,223	16,841	588
1995	11,853	4,752	16,605	0.18013	12,892	23.98	5,695	18,588	1,983
1996	11,853	5,132	16,985	0.19989	14,307	26.05	6,187	20,493	3,509
1997	11,853	5,542	17,395	0.23697	16,960	28.31	6,724	23,684	6,289
1998	12,733	5,986	18,719	0.26931	19,275	30.76	7,306	26,581	7,862
1999	12,733	6,465	19,198	0.29903	21,402	33.43	7,940	29,342	10,144
2000	12,733	6,982	19,715	0.32782	23,463	36.35	8,633	32,096	12,381
2001	12,733	7,540	20,273	0.35406	25,341	39.26	9,324	34,665	14,392
2002	12,733	8,143	20,876	0.38343	27,443	42.40	10,070	37,513	16,636
2003	12,733	8,795	21,528	0.39448	28,234	45.79	10,875	39,109	17,581
2004	12,733	9,499	22,232	0.43230	30,941	49.46	11,747	42,687	20,456
2005	12,733	10,258	22,991	0.47127	33,730	53.41	12,685	46,415	23,423
2006	12,733	11,079	23,812	0.50118	35,871	57.68	13,699	49,570	25,757
2007	2,933	11,965	14,898	0.53340	38,177	62.30	14,796	52,973	38,074
2008	2,933	12,923	15,856	0.56807	40,658	67.28	15,979	56,637	40,781
2009	2,933	13,956	16,889	0.60499	43,300	72.67	17,259	60,560	43,670
2010	2,933	15,073	18,006	0.64431	46,115	78.48	18,639	64,754	46,748

Table 9-9

Cash Flow Forecast -- Full Steam Loop (3A)
(New York State Power Pool Electric Rates -- Oil and O&M Steam Rates)

Year	Debt Payments $1,000	O&M Costs $1,000	Total Annual Costs $1,000	Electricity Rates $/kWh	Electricity Revenues $1,000	Steam Rates $/1,000 lbs	Steam Revenues $1,000	Total Annual Revenues $1,000	Difference in Revenues Minus Cost $1,000
1986	$13,476	$ 3,084	$16,560	$0.07700	$ 3,342	$10.31	$ 5,650	$ 8,991	$(7,569)
1987	13,476	3,331	16,807	0.08164	3,543	11.25	6,165	9,708	(7,099)
1988	13,476	3,597	17,073	0.09537	4,139	12.35	6,768	10,907	(6,167)
1989	13,476	3,885	17,361	0.10482	4,549	13.53	7,414	11,963	(5,398)
1990	13,476	4,196	17,672	0.11260	4,887	14.79	8,105	12,991	(4,680)
1991	13,476	4,531	18,007	0.12393	5,378	16.12	8,834	14,212	(3,795)
1992	13,476	4,894	18,370	0.13026	5,653	17.56	9,623	15,276	(3,094)
1993	13,476	5,285	18,761	0.13877	6,022	19.15	10,494	16,516	(2,245)
1994	19,352	5,708	25,060	0.16233	7,045	20.87	11,437	18,481	(6,579)
1995	19,352	6,165	25,517	0.18013	7,817	22.78	12,483	20,301	(5,216)
1996	19,352	6,658	26,010	0.19989	8,675	24.75	13,563	22,238	(3,772)
1997	19,352	7,191	26,543	0.23697	10,284	26.92	14,752	25,036	(1,507)
1998	20,232	7,766	27,998	0.26931	11,687	29.26	16,034	27,722	(276)
1999	20,232	8,387	28,619	0.29903	12,977	31.80	17,426	30,404	1,784
2000	20,232	9,058	29,290	0.32782	14,227	34.59	18,955	33,182	3,892
2001	20,232	9,783	30,015	0.35406	15,365	37.35	20,468	35,833	5,818
2002	20,232	10,566	30,798	0.38343	16,640	40.34	22,106	38,746	7,949
2003	20,232	11,411	31,643	0.39448	17,119	43.58	23,882	41,001	9,358
2004	20,232	12,324	32,556	0.43230	18,761	47.06	25,789	44,550	11,994
2005	20,232	13,310	33,542	0.47127	20,452	50.82	27,849	48,301	14,760
2006	20,232	14,374	34,606	0.50118	21,750	54.88	30,074	51,824	17,218
2007	2,933	15,524	18,457	0.53340	23,148	59.28	32,485	55,634	37,176
2008	2,933	16,766	19,699	0.56807	24,653	64.02	35,083	59,736	40,037
2009	2,933	18,108	21,041	0.60499	26,255	69.14	37,889	64,144	43,103
2010	2,933	19,556	22,489	0.64431	27,962	74.67	40,919	68,881	46,391

Table 9-10

Cash Flow Forecast -- Full Steam Loop (3B)
(New York State Power Pool Electric Rates -- Oil and O&M Steam Rates)

Year	Debt Payments $1,000	O&M Costs $1,000	Total Annual Costs $1,000	Electricity Rates $/kWh	Electricity Revenues $1,000	Steam Rates $/1,000 lbs	Steam Revenues $1,000	Total Annual Revenues $1,000	Difference in Revenues Minus Cost $1,000
1986	$13,476	$ 3,084	$16,560	$0.07700	$ 3,342	$11.57	$ 6,340	$ 9,682	$(6,878)
1987	13,476	3,331	16,807	0.08164	3,543	12.65	6,932	10,475	(6,332)
1988	13,476	3,597	17,073	0.09537	4,139	13.83	7,579	11,718	(5,356)
1989	13,476	3,885	17,361	0.10482	4,549	15.12	8,286	12,835	(4,526)
1990	13,476	4,196	17,672	0.11260	4,887	16.50	9,042	13,929	(3,743)
1991	13,476	4,531	18,007	0.12393	5,378	17.97	9,848	15,226	(2,782)
1992	13,476	4,894	18,370	0.13026	5,653	19.57	10,724	16,377	(1,993)
1993	13,476	5,285	18,761	0.13877	6,022	21.31	11,678	17,700	(1,061)
1994	19,352	5,708	25,060	0.16233	7,045	23.21	12,719	19,764	(5,296)
1995	19,352	6,165	25,517	0.18013	7,817	25.30	13,864	21,682	(3,835)
1996	19,352	6,658	26,010	0.19989	8,675	27.48	15,059	23,734	(2,276)
1997	19,352	7,191	26,543	0.23697	10,284	29.85	16,358	26,642	99
1998	20,232	7,766	27,998	0.26931	11,687	32.43	17,772	29,459	1,461
1999	20,232	8,387	28,619	0.29903	12,977	35.23	19,306	32,283	3,664
2000	20,232	9,058	29,290	0.32782	14,227	38.29	20,983	35,210	5,919
2001	20,232	9,783	30,015	0.35406	15,365	41.36	22,665	38,031	8,016
2002	20,232	10,566	30,798	0.38343	16,640	44.66	24,474	41,114	10,316
2003	20,232	11,411	31,643	0.39448	17,119	48.24	26,436	43,555	11,912
2004	20,232	12,324	32,556	0.43230	18,761	52.10	28,551	47,312	14,756
2005	20,232	13,310	33,542	0.47127	20,452	56.26	30,830	51,282	17,741
2006	20,232	14,374	34,606	0.50118	21,750	60.76	33,296	55,046	20,440
2007	2,933	15,524	18,457	0.53340	23,148	65.63	35,965	59,114	40,656
2008	2,933	16,766	19,699	0.56807	24,653	70.88	38,842	63,495	43,796
2009	2,933	18,108	21,041	0.60499	26,255	76.55	41,949	68,205	47,164
2010	2,933	19,556	22,489	0.64431	27,962	82.67	45,303	73,265	50,775

9.3 MATERIAL RECOVERY ALTERNATIVES -- EQUIPMENT COSTS

Alternatives for materials recovery have been presented in Section 7. These alternatives include material recovery strategies which are based on partial and total recovery concepts. Costs developed for each of these alternatives do not include owner financing costs or escalation over the life of the facility. A 15-year life was assumed for cost-estimating purposes.

9.3.1 Partial Recovery Concepts

Installed equipment costs for three partial recovery concepts have been presented in Table 7-4, and are summarized as follows:

Ferrous only	$520,000
Aggregate only	$645,000
Ferrous and aggregate	$796,500

For each of these alternatives, the quantity of material disposed at Fresh Kills is reduced but not eliminated. A portion of the residue is still destined for ultimate landfill disposal.

9.3.2 Total Recovery Concepts

Estimates of installed equipment costs for the two total recovery concepts have been presented in Table 7-5, and are summarized as follows:

Ferrous resale with aggregate	$856,500
Ferrous resale or total aggregate	$945,500

Both toal recovery concepts eliminate the requirement for landfill disposal during periods of normal operation.

9.3.3 Total Capital and Operating Costs

Installed equipment costs for each alternative have been adjusted to include:

1. Design engineering, and construction management.
2. Contingency.

Total capital and operating costs for partial recovery concepts are shown in Table 9-11; capital and operating costs for the total recovery concepts are presented in Table 9-12. The total annual costs presented in Tables 9-11 and 9-12 include power requirements, chemicals, manpower, and debt service costs at 8 percent with a 15-year equipment life.

Table 9-11

Total Capital and Operating Costs -- Partial Recovery Concepts

Item	1 Ferrous Only	2 Aggregate Only	3 Ferrous and Aggregate
Capital Costs			
Installed equipment costs	$520,000	$645,000	$ 796,500
Design engineering and construction management at 20%	104,000	129,000	159,000
Contingency at 15%	94,000	116,000	143,000
Total	$718,000	$890,000	$1,089,500
Operating Costs			
Maintenance (3% of capital costs)	$ 16,000	$ 19,000	$ 24,000
Power (at $0.10/kWh)	29,000	36,000	28,000
Manpower (at $30,000/year)	30,000	30,000	30,000
Lime (at $60/ton)	--	110,000	110,000
Total	$ 75,000	$195,000	$ 202,000
Total Annual Costs			
Debt service (8%, 15 years)	$ 84,000	$104,000	$ 128,000
Operating costs	75,000	195,000	202,000
	$159,000	$299,000	$ 330,000

Table 9-12

Capital and Operating Costs -- Total Recovery Concepts

Item Capital Costs	4 Ferrous Resale with Residue Aggregate	5 Ferrous Resale or Total Aggregate
Installed equipment costs	$ 856,500	$ 945,500
Design engineering and construction management at 20%	171,000	189,000
Contingency at 15%	154,000	170,000
Total	$1,181,500	$1,304,500

Operating Annual Costs		Total Aggregate	Ferrous Resale
Maintenance (3% of capital costs)	$ 26,000	$ 28,000	$ 28,000
Power (at $0.10/kWh)	50,000	65,000	50,000
Manpower (at $30,000/year)	45,000	60,000	45,000
Lime (at $60/ton)	125,000	171,000	125,000
Total	$246,000	$324,000	$ 248,000
Total Annual Costs			
Debt service (8%, 15 years)	$138,000	$152,000	$ 152,000
Operating costs	246,000	324,000	248,000
	$384,000	$476,000	$ 400,000

9.3.4 Projected Revenues

For each alternative, projected revenues were calculated for both a City-owned and privately-owned recovery facility. Revenues for the partial and total recovery alternatives are presented in Tables 9-13 and 9-14, respectively.

Since Alternative 5 (ferrous resale or total aggregate) may be operated to produce either all aggregate or aggregate and processed ferrous for resale, two sets of operating costs and revenues are presented in Tables 9-12 and 9-14, respectively. These represent the different costs and revenues associated with operating Alternative 5 under each scenario.

A selling price of $10 per ton was assumed for ferrous metals sold to a scrap dealer by a City-owned facility. This price was representative of those encountered in this study. It was assumed that the privately-owned facility would realize a 20 percent increased profit on ferrous sales, or $12 per ton. This assumes that a scrap dealer would operate the facility, eliminating the existing middleman (i.e., the scrap dealer) in a City-owned facility. Conversely, revenues resulting from the replacement of aggregate material at the asphalt plant result in a savings of $10 per ton to the City. This corresponds to the current price paid by the City for aggregate materials. The privately-owned facility was assumed to realize a gross revenue of $7 per ton from supplying screened aggregate to the asphalt plant. This assumes that a $3 per ton incentive would be required for the City to purchase this aggregate.

For the City-owned facility, additional benefit would be realized by diverting the residue from the Fresh Kills Landfill. The current disposal cost at Fresh Kills is $11.89 per ton, $5.30 of which is capital, $6.59 is operation and maintenance. For the purposes of estimating landfill and barging cost savings, it was assumed that 50 percent of the operation and maintenance cost could be saved under the partial recovery concepts, while 80 percent savings could be realized with the total recovery concepts. No capital cost savings were assumed. Total revenues presented in Tables 9-13 and 9-14 have been calculated with and without the projected savings.

Table 9-13

Projected Revenues -- Partial Recovery Concepts

Item	1 Ferrous Only	2 Aggregate Only	3 Ferrous and Aggregate
City-Operated Facility			
Ferrous metal (at $10/ton)	$153,000	--	$153,000
Aggregate (at $10/ton)	--	389,000	389,000
Total revenue	$153,000	$389,000	$542,000
Net revenue[1]	(6,000)	90,000	212,000
Payback period (years)	--	9.9	5.2
Landfill recovery (at $3.30/ton)	50,600	121,300	171,900
Total revenue	$203,600	$510,300	$713,900
Net revenue[1]	44,600	211,300	383,900
Payback period (years)	16.3	4.2	2.9
Privately-Operated Facility			
Ferrous metal (at $12/ton)	$184,000	--	$184,000
Aggregate (at $7/ton)	--	272,000	272,000
Total revenue	$184,000	$272,000	$456,000
Net revenue[1]	25,000	(27,000)	126,000
Payback period (years)	28.7	--	8.7

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[1] Total revenue minus total annual cost (Table 9-11).

Table 9-14

Projected Revenues -- Total Recovery Concepts

Item	4	5	
	Ferrous Resale with Residue Aggregate	Ferrous Resale or Total Aggregate	
		All Aggregate	Ferrous Resale
City-Operated Facility			
Ferrous metal (at $10/ton)	$153,000	--	$153,000
Aggregate (at $10/ton)	419,000	548,000	419,000
Total revenue	$572,000	$548,000	$572,000
Net revenue[1]	188,000	72,000	172,000
Payback period (years)	6.3	18.1	7.6
Landfill recovery (at $3.30/ton)	289,000	289,000	289,000
Total revenue	$861,000	$837,000	$861,000
Net revenue[1]	477,000	361,000	461,000
Payback period (years)	2.5	3.6	2.8
Privately-Operated Facility			
Ferrous metal (at $12/ton)	$184,000	--	$184,000
Aggregate (at $7/ton)	293,000	384,000	293,000
Total revenue	$477,000	$384,000	$477,000
Net revenue[1]	93,000	(92,000)	77,000
Payback period (years)	12.7	--	16.9

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[1] Total revenue minus total annual cost (Table 9-12).

9.4 AIR POLLUTION CONTROL EQUIPMENT

As discussed in Section 8, operation of the incinerator complex at a design processing rate of 1,000 tpd will require the replacement of the air pollution control system presently installed on furnace No. 1. Concept design and equipment costs for the installation of a new down-flow gas-conditioning tower and electrostatic precipitator are presented in Table 8-1. Total capital costs presented in Table 9-15 have been adjusted to include:

1. Design engineering, and construction management.
2. Contingency.

The total cost for the installation of this equipment is $5,139,700, which does not include any bond issues or owner's costs.

Table 9-15

Total Capital Cost -- Air Pollution Control Equipment

Item	Cost
Installed equipment cost	$3,724,400
Design engineering, and construction management at 20%	744,900
Contingency at 15%	670,400
Total Equipment Cost	$5,139,700

SECTION 10

ANALYSIS OF ALTERNATIVES AND RECOMMENDATIONS

10.1 INTRODUCTION

The analysis of alternatives for energy and material recovery and air pollution control (presented in Section 9), along with recommended alternatives and recommendations for additional activities, are presented in this section. The various energy and material recovery alternatives presented were evaluated with respect to:

1. Present-worth analysis.
2. Implementation requirements.
3. Environmental requirements.

10.2 ENERGY RECOVERY

10.2.1 Present-Worth Analysis

A present-worth analysis was performed on the projected cash flow for each energy recovery alternative presented in Section 9. Each alternative was evaluated by comparing the ratio of the present worth of the net revenue surplus divided by the present worth of the total project cost (net surplus ratio). The total project costs were developed by adding the amount of the total bond issue to the present worth (1986) of the projected annual O&M costs. The net surplus was calculated by subtracting the total project cost from the present worth of the total revenues. A summary of these data is presented in Table 10-1.

Of the three alternatives examined, the electricity-only alternative generates the highest net surplus ratio. The electricity-only alternative produces lower total revenues than any of the three alternatives, but also requires a lower initial investment. The partial-steam loop cogeneration alternative generates the second most favorable ratio. The full steam loop cogeneration alternative produces the highest amount of total revenues, but is the least attractive alternative because of the large capital investment required. In addition, on a cash-flow basis (presented in Tables 9-6 through 9-10), the electricity-only alternative yields three years of negative cash flow, the partial steam loop cogeneration alternative yields four years of negative cash flow, and full steam loop alternative yields 11 years of negative cash flow.

Table 10-1

Present-Worth Analysis (1986 $) -- Energy Recovery Alternatives[1]

Alternative[2]	Total Bond Issue[3] $1,000	Total Annual O&M Cost $1,000	Total Project Cost $1,000	Total Revenues $1,000	Net Surplus $1,000	Net Surplus Ratio
1A Electricity	$69,585	$44,963	$114,548	$180,846	$ 66,298	0.58
2A Partial Steam Loop	82,571	48,100	130,671	192,482	61,811	0.47
2B Partial Steam Loop	82,571	48,100	130,671	195,383	64,712	0.50
3A Full Steam Loop	133,173	62,405	195,578	209,321	13,743	0.07
3B Full Steam Loop	133,173	62,405	195,578	223,340	27,762	0.14

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[1] Based on 27.5-year bonds issued in January 1984.
[2] Specific alternatives are presented in subsection 9.2.6.
[3] Includes boiler replacement in 1998.

10.2.2 Implementation Requirements

Implementation of either cogeneration alternative will require the construction of a steam distribution system in an area which is primarily residential. This construction will result in some traffic-only disruption in the area, and will have future maintenance requirements.

The operation of either cogeneration option will require negotiations between steam consumers and the plant to arrive at mutually-agreeable terms for energy rates.

Implementation of the electricity-only option is simplified due to the fact that all construction associated with this alternative is located on-site. Electricity generated in the plant will be sold directly to Consolidated Edison, therefore, the electricity-only alternative has the minimal implementation requirements.

The modifications required for the existing installation are discussed in subsection 6.2 and are identical for all alternatives.

10.2.3 Environmental and Licensing Requirements

With the exception of those effects directly associated with construction of the steam distribution network, the environmental requirements for each energy alternative are identical and, for the most part, associated with the heat rejection system. The available alternatives include the use of cooling towers or once-through cooling. The selection of the heat rejection system will have an effect on the licensing time for the facility (see Figure 9-1).

Preliminary discussions with the New York Department of Environmental Conservation and the New York City Department of Environmental Protection (see Appendix O) indicate that the participation of PASNY and the City in the project triggers the state and municipal environmental review process. If both the state and City desire to examine the environmental impacts of the project, a lead agency will be be selected to coordinate a joint project review. To initiate the environmental review process, an Environmental Report (ER) summarizing the environmental impacts of the project must be submitted. After the environmental review process is completed, the required City and state permits can be issued.

The use of once-through cooling could result in a significant licensing effort. The once-through cooling system would require the construction of intake and discharge structures in navigable waters. In order to begin this construction, a permit would be required for the U.S. Army Corps of Engineers. Prior to issuing the permit, the Corps would be required to either make a finding of no significant impact, or to prepare and publish an Environmental Impact Statement. In either case, significant environmental information must be supplied as part of the permit application.

The utilization of a once-through cooling system will also require a waiver from the effluent standards as part of a state pollutant discharge elimination system (SPDES) permit. This waiver is generally referred to as a "316a waiver." To obtain this waiver a significant amount of water quality sampling may be required. The Department of Environmental Conservation regulations require that any applicant must consult with the Department to determine what studies are necessary. These studies could consist of detailed sampling programs extending for as long as a full year, and the use of computer modeling to determine the thermal discharge effects. There is also a possibility that upon reviewing the 316a waiver application and the results of the studies, the agency could determine that once-through cooling was not acceptable and would require the use of cooling towers. In addition, Section 316b of the Clean Water Act requires that the location, design, and capacity of any intake structure reflect Best Available Technology for minimizing adverse environmental effects. This regulation may also require baseline larval fish and aquatic organism surveys to provide the required information.

The licensing effort for once-through cooling could, under the most probable conditions, add approximately one year to the licensing schedule. This time could be shorter or longer, depending on specific questions or concerns raised by agencies or citizen environmental groups.

With respect to the utilization of cooling towers, at this time it appears that a state pollutant discharge elimination system permit will not be required since the use of cooling towers allows the facility to discharge its wastewater to the sewer system. However, the City will review all discharges to the sewers and can impose any pretreatment requirements necessary to protect its sewer system and treatment facilities. Based on the quantities to be discharged and the water treatment to be used it does not appear that blowdown will require pretreatment. (The blowdown from the plant would average 0.24 x 10^6 gpd, or 0.1 percent of the Owls Head wastewater treatment plant capacity of 250 x 10^6 gpd.)

Since the incinerator will shortly be authorized for 24 hrs/day, 7 days/week operation, a Prevention of Significant Deterioration (PSD) permit will be required. It may be necessary, however, to have the City amend the operation permit issued for the incinerator in order to install the waste heat boilers. It is expected that the pretreatment review and operation permit amendments can be issued shortly after completion of the environmental review process. In summary, six months is anticipated as the time required for licensing the project, based on using a cooling tower to dissipate the waste heat.

The use of a cooling tower was selected as the recommended heat rejection alternative as a result of reduced licensing requirements, thereby reducing the overall cost of the project. A wet/dry plume abatement cooling tower will eliminate any potential adverse impact for icing or fogging in the surrounding area.

10.2.4 Recommended Alternative

The electricity-only option was selected as the recommended alternative because it resulted in the highest net surplus ratio, has the most favorable cash-flow projections, is the simplest to implement, and has the flexibility to incorporate steam or hot water distribution in the future.

10.3 MATERIAL RECOVERY

10.3.1 Present-Worth Analysis

Total project costs for each materials recovery alternative (presented in Section 9) were calculated by adding the total capital cost to the present worth of the total annual costs over the 15-year life of the recovery facility. Total revenues for each option were calculated both with and without the savings attributed to landfill recovery.[1] For the purposes of this evaluation, only the revenues associated with a City-owned facility are presented.

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[1] Landfill recovery includes a cost savings associated with a reduction in City operating costs for transporting and disposing of the incinerator ash.

For the analyses which include landfill recovery, the total recovery option which reclaims ferrous and aggregate provides the highest net surplus ratio. Analyses performed without landfill recovery revenues indicated that the partial recovery option which reclaims ferrous and aggregate provides the highest net surplus ratio. A summary of the present worth analysis is presented in Table 10-2.

10.3.2 Implementation Requirements

The implementation of each of the partial recovery alternatives utilizes the applied technology of ferrous metal separation and the successful small-scale testing of incinerator residue as aggregate extender in bituminous mixtures. Each of the total recovery alternatives requires the installation of mechanical shredders. These shredders are high maintenance items and are not usually associated with incinerator residue operations. Data presented by the Bureau of Mines have indicated successful operation of mechanical hammermill shredders to reduce the size of incinerator residue.

Both recovery alternatives (total and partial) will require the establishment of mutually-acceptable rate structures for the sale of ferrous scrap and aggregate. Each option which includes aggregate recovery will require laboratory characterizations and residue mix analyses. A test program involving the installation of street pavement, as outlined in Appendix G, may also be required to evaluate the resulting experimental asphalt mixtures.

10.3.3 Environmental Requirements

The major environmental concerns associated with the disposal of incinerator residue (i.e., leaching of potentially hazardous materials into ground or surface waters) are reduced or eliminated by the implementation of material recovery. The utilization of incinerator residue as an aggregate material in bituminous mixtures is more desirable than landfill disposal, and is a technology currently under consideration as a means of hazardous waste treatment. Encapsulating the residue in asphalt reduces the leachability of the material.

The total recovery options have the environmental benefit of eliminating landfill disposal and barging requirements under normal operations. Each of the partial recovery options provides similar benefits, to a lesser degree, by the reduction of landfill disposal requirements.

Table 10-2

Evaluated Project Cash Flow Analysis (1981 $) -- Materials Recovery Alternatives[1]

Alternative	Capital Cost $1,000	Annual Cost $1,000	Total Project Cost $1,000	Total Revenue $1,000		Net Surplus $1,000		Net Surplus Ratio	
				Without Landfill Recovery	With Landfill Recovery	Without Landfill Recovery	With Landfill Recovery	Without Landfill Recovery	With Landfill Recovery
Partial Recovery									
Ferrous only	$ 718	$ 643	$1,361	$1,310	$1,746	$ 51	$ 385	-0.04	0.28
Aggregate only	890	1,669	3,559	3,329	4,365	770	1,806	0.30	0.71
Ferrous and aggregate	1,089	1,735	2,824	4,639	6,111	1,815	3,287	0.64	1.16
Total Recovery									
Ferrous and aggregate	1,182	2,105	3,287	4,896	7,369	1,609	4,082	0.49	1.24
Aggregate only	1,305	2,769	4,074	4,690	7,164	616	3,090	0.15	0.76
Aggregate and ferrous resale	1,305	2,119	3,424	4,896	7,369	1,472	3,945	0.43	1.15

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[1] Based on a 15-year project life.

Potential environmental impacts may result from dust generated by aggregate recovery options. This problem can be mitigated, in most cases, by separating precipitator fly ash from incinerator residue prior to material recovery operations.

10.3.4 Recommended Alternative

The partial recovery option for ferrous and aggregate recovery has been selected as the recommended alternative for several reasons. This option provides the highest net surplus ratio for cost analyses which exclude landfill recovery revenues. When landfill recovery is considered, this option still provides the second highest surplus ratios. From an implementation perspective, this option requires the least equipment and eliminates the need for a high maintenance shredder. In addition, this alternative can be expanded to incorporate total recovery if the partial concept proves to be highly successful.

10.4 AIR POLLUTION CONTROL

The operation of the incinerator complex at the design rate of 1,000 tpd will require the installation of air pollution control equipment on furnace No. 1, as proposed in Section 8.

10.5 RECOMMENDATIONS FOR ADDITIONAL STUDIES

Prior to startup of the final engineering design phase (see Figure 9-1), it is recommended that more detailed investigations be undertaken which would include the following:

1. Review the various boiler configurations offered by equipment vendors, their materials of construction, maintenance requirements, and susceptibility to corrosion, and projected performance changes under dirty gas applications to assess in detail the advantages and disadvantages of proposed systems (see subsection 6.3)

2. Evaluate, based on vendor drawings, the optimum locations for the boilers and turbine-generator, providing an assessment of the structural requirements of the various alternatives under consideration (see subsection 6.5.9).

3. Evaluate in greater depth the potential heat sources for underfire air preheating (e.g., extraction steam, wall cooling air, etc.).

4. Determine the definitive requirements (see Table 6-1) and costs for upgrading and operating the existing incinerator facility to generate steam and electricity.

These tasks are intended to confirm and optimize the design criteria and cost data presented in this report, and to provide additional data that will aid in determining the total capital and operating costs of the entire integrated facility. These additional studies would not alter the conclusions presented in this report, but would provide a more accurate assessment of total costs.

With respect to steam or hot water district heating, the following recommendations are made:

1. Further investigation be undertaken to assess the benefits of hot water relative to steam for use as a district heating medium.

2. Additional analyses be conducted to assess the feasibility of providing heat for several new buildings, i.e., a new 162-unit condominium currently under construction 2 blocks south of the site, a local sanitation maintenance garage (presently under design), and a new car dealership recently constructed.

These recommendations are intended to reassess the increased potential for district heating in the vicinity of the facility.

With respect to material recovery, the following recommendations are made:

1. The Office of Resource Recovery in conjunction with the Department of Transportion, should proceed with a sampling and laboratory program to characterize the incinerator residue for use as asphalt aggregate, and upon completion proceed with a field test program to examine its viability on New York City streets.

2. The Office of Resource Recovery should solicit further input from the Institute of Scrap Iron and Steel with respect to their interest in purchasing residue metals separated magnetically (see Section 7).

These additional studies are intended to confirm the technical and economic feasibility of the material recovery recommendations presented in this report.

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APPENDIX A

REFUSE QUANTITIES

APPENDIX B

FIELD TESTING PROGRAM

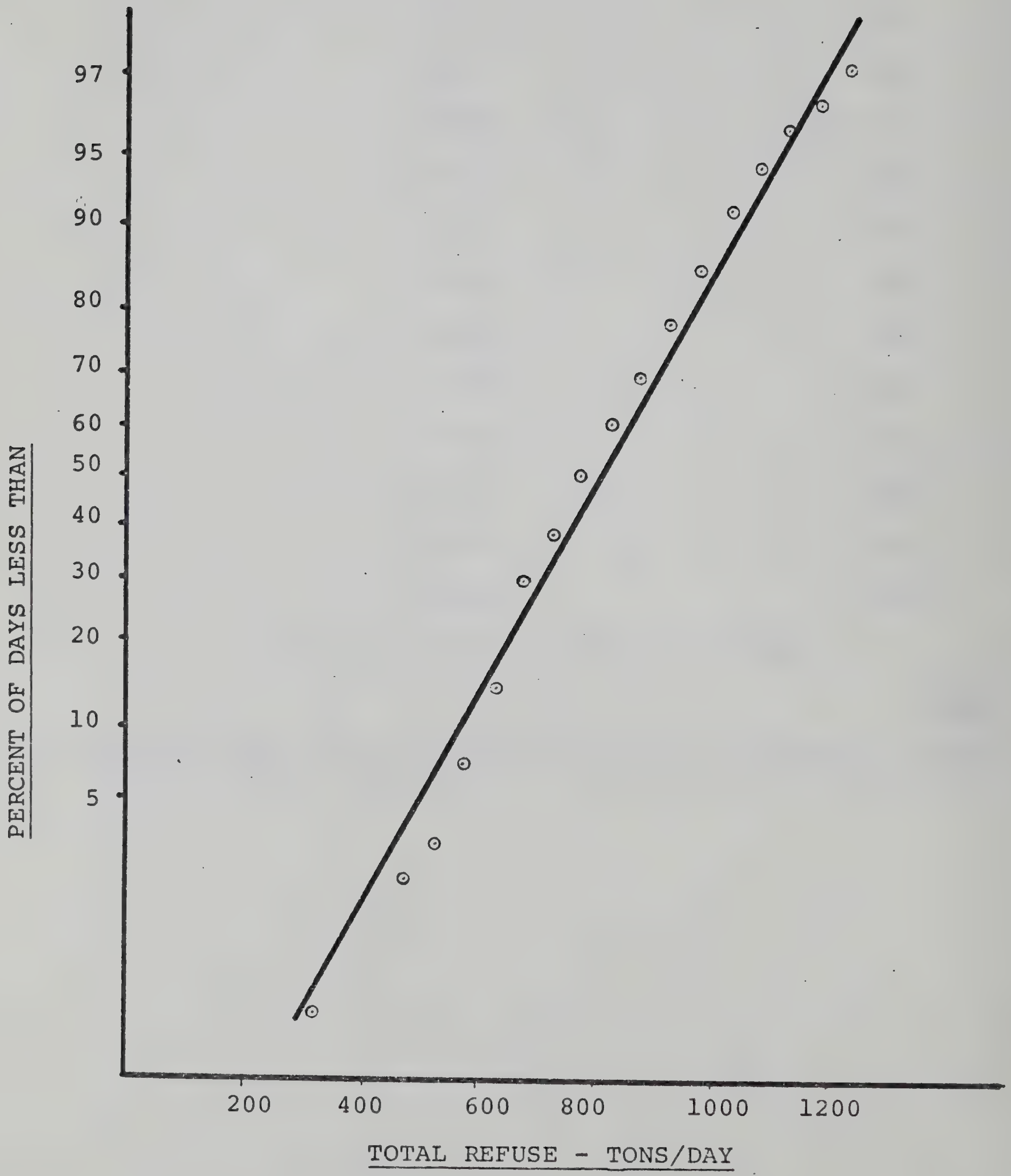
TABLE A-1 MONTHLY SUMMARY OF REFUSE DELIVERED

MONTH	AVERAGE TOTAL REFUSE (TONS/DAY)
Nov 79	817.1
Dec	872.6
Jan 80	957.2
Feb	739.5
Mar	786.1
Apr	861.9
May	860.4
Jun	843.6
Jul	829.9
Aug	785.4
Sep	769.5
Oct	688.1
YEARLY AVERAGE	817.6 Tons/day

Note:

Refuse quantities required to achieve 1,000 tpd have been confirmed by the City of New York Department of Sanitation.

FIGURE A-1 FREQUENCY DISTRIBUTION OF TOTAL REFUSE DELIVERED



APPENDIX B

FIELD TESTING PROGRAM

To assist in defining the actual heat value at the Southwest Brooklyn Incinerator, a sampling program was undertaken during the week of 16-21 March 1981. The primary goal of the field program was to establish the total heat value of the flue gases leaving the secondary chamber at the design throughput rate of 250 tpd.

Implementation of the field program was accomplished by monitoring refuse throughput, air temperatures, and flow rates; and conducting ORSAT analyses at selected locations. Individual tasks included:

1. Calibration of refuse throughput rate with grate speed.
2. Measurement of forced-air flow rates from three forced-air fans.
3. Measurement of air temperatures in secondary chamber.
4. ORSAT analysis of secondary chamber gases and stack gases.
5. Measurement of total stack gas flow rates.
6. Measurement of temperature drop across gas-conditioning tower at measured flow rates.
7. Measurement of pressure drop across air pollution control train.

Figure B-4 is a schematic representation of the incinerator gas flow path, and depicts the sampling stations and test descriptions.

TASK 1: CALIBRATION OF REFUSE THROUGHPUT RATE WITH GRATE SPEED

Procedure: For each day of operation, charging floor personnel were instructed to record the toal number of buckets charged to the furnace (No. 2). Data sheets were provided for bucket counts and to record time of day. Over the course of the program, twelve buckets were weighed using a dump truck and the truck scale. Upper grate speeds were set once per day and remained unchanged for the remainder of that day.

Results: Data plotted in Figure B-1 show an excellent correlation between refuse throughput and grate speed. Refuse throughput was determined using the actual bucket counts taken and the average bucket weight measured at 1.15 tons. These data are reported in Table B-1.

TASK 2: MEASUREMENT OF FORCED-AIR FLOWS

Procedure: Measurements were taken in the underfire, overfire, and wall cooling air ducts in conformance with EPA Method 1. Test parts were drilled into the ductwork at locations conforming to Method 1 wherever possible. Two velocity profiles were taken at each location to verify flow conditions for each day. Fan settings were adjusted once per day and remained unchanged for the remainder of that day. Notations of damper settings were made so as to develop flow calibration curves for both the overfire and underfire fans.

Results: Measurements taken for each day were averaged and reported in Table B-1. Stoichiometric air requirements were calculated using 3.43 lb air/lb refuse. Calibration curves for the overfire and underfire air fans are presented in Figure B-2.

TASK 3: MEASUREMENTS OF AIR TEMPERATURES IN SECONDARY CHAMBER

Procedure: Temperature measurements were taken at the viewing port in the secondary chamber using a 10-foot thermocouple with digital readout. A traverse of 8 readings at one foot intervals was taken once per day concurrently with total stack gas flow rate measurements.

Results: Average secondary chamber temperatures are reported in Table B-1. Furnace temperatures reported in Table B-1 were averaged from hourly data collected by NYC personnel.

TASK 4: CALCULATION OF SECONDARY CHAMBER FLOW RATES

Purpose: ORSAT analyses, which provide a breakdown of gas composition, were used to collaborate total forced air measurements taken in the fan ductwork.

Procedure: ORSAT analyses were taken simultaneously at the stack test ports and the secondary chamber. Measured CO_2 concentrations were used in conjunction with measured stack gas flowrates to back-calculate air flows at the secondary chamber by mass balance. These calculations were based on the assumption that the combustion of the flue gases was essentially complete by the rear of the secondary chamber.

Results: Calculated secondary air flows for each day are reported in Table B-1, and show reasonably good correlation with measured forced air flows. The analysis indicated a substantial amount of infiltration occurs between the secondary chamber and the stack.

TASK 5: MEASUREMENT OF TOTAL STACK GAS FLOW RATES

Procedure: Velocity profiles were taken at the existing stack sampling ports using pilot tubes. Measurements were taken to correspond with EPA Method 1 as closely as possible. Lack of sufficient clearance prevented the entire traverse to be taken at one of the two sampling ports. Flow rates were adjusted for temperature and moisture content as per EPA Method 1.

Results: Total stack flows measured for each day have been reported in Table B-1.

TASK 6: MEASUREMENT OF TEMPERATURE DROP ACROSS GAS-CONDITIONING TOWER

Purpose: To ascertain the total temperature drop to be encountered across the tower with the water sprays disabled.

Procedure: With the furnace in operation, the induced-draft fan was activated at a speed of 180 rpm and the inlet damper was opened 6". Care was taken not to thermally-shock the refractory-lined GCT or allow the inlet temperature to the precipitator to exceed 550°F. Fan speed was slowly increased and the damper was opened to allow the gas temperature to rise. After allowing the temperatures to stabilize for three hours, temperature and flow readings were taken.

Results: Stabilized temperature measurements, shown in Figure B-3, indicated a loss of 215°F across the GCT at a gas flow rate of 17,900 scfm. These data are extrapolated to actual conditions in Appendix C.

TASK 7: MEASUREMENT OF PRESSURE DROP ACROSS APC TRAIN

Purpose: To determine adequacy of existing induced-draft fan and drive.

Procedure: After allowing the furnace to cool below 200°F, the stack damper was closed, the APC damper was opened, and the induced-draft fan was brought up to 690 rpm. Pressure readings were taken in the furnace, secondary chamber, GCT uptake flue, precipitator inlet, and fan inlet. Total flow was measured using EPA Method 1 in the GCT uptake flue.

Results: Pressure readings taken are presented in Table B-2 and indicate a total pressure drop of 3.6 in H_2O across the entire system. Pressure drop across the APC train was measured at 2.5 in H_2O at a gas flow rate of 98,100 scfm.

TABLE B-1

DATA SUMMARY - AIR & TEMPERATURE MEASUREMENTS

DATE	GRATE SPEED	THROUGHPUT		AIR FLOWS (scfm)							% EXCESS AIR	TEMPERATURE (°F)	
		BUCKETS PER HR	TPD	UFA	OFA	WC	TOT	STACK	DOGHOUSE	STOIC		FURNACE	DOGHOUSE
3-16	3½	6	165	14,600	7,700	6,200	28,500	79,800	27,300	10,300	175	1,600	1,250
								80,100	29,700				1,205
3-17	5½	9	248	18,100	18,100	6,600	42,800	86,800	31,500	15,500	175	1,575	1,395
								82,000	31,800				1,295
3-18	6½	10.6	292							18,200		1,640	1,840
3-19	4	6.4	177	15,600	15,000	6,700	37,300	88,000	32,400	11,000	240		1,120
								91,900	44,200				
3-20	6½	10.4	288	19,300	16,300	6,300	41,900	99,200	39,300	18,000	135		1,450
								95,200	33,800				1,585
3-21	7½	12.5	345	14,200	18,900	6,100	39,200	96,900	22,100	21,500	80		1,585
													1,590

TABLE B-2

PRESSURE DROP MEASUREMENTS

MONITORING LOCATION	FAN SPEED (rpm)	CURRENT (amps)	STATIC PRESSURE ("H_2O)	Q_{GCT} (scfm)	Q_{Stack} (scfm)	GAS TEMP (°F
ID FAN INLET	690	410	-3.8	98,100	102,500	170
PRECIPITATE INLET			-2.8			
GCT UPTAKE FLUE			-1.3			
SECONDARY CHAMBER			-0.60			
FURNACE			-0.22			

FIGURE B-1

REFUSE THROUGHPUT
VS. GRATE SPEED

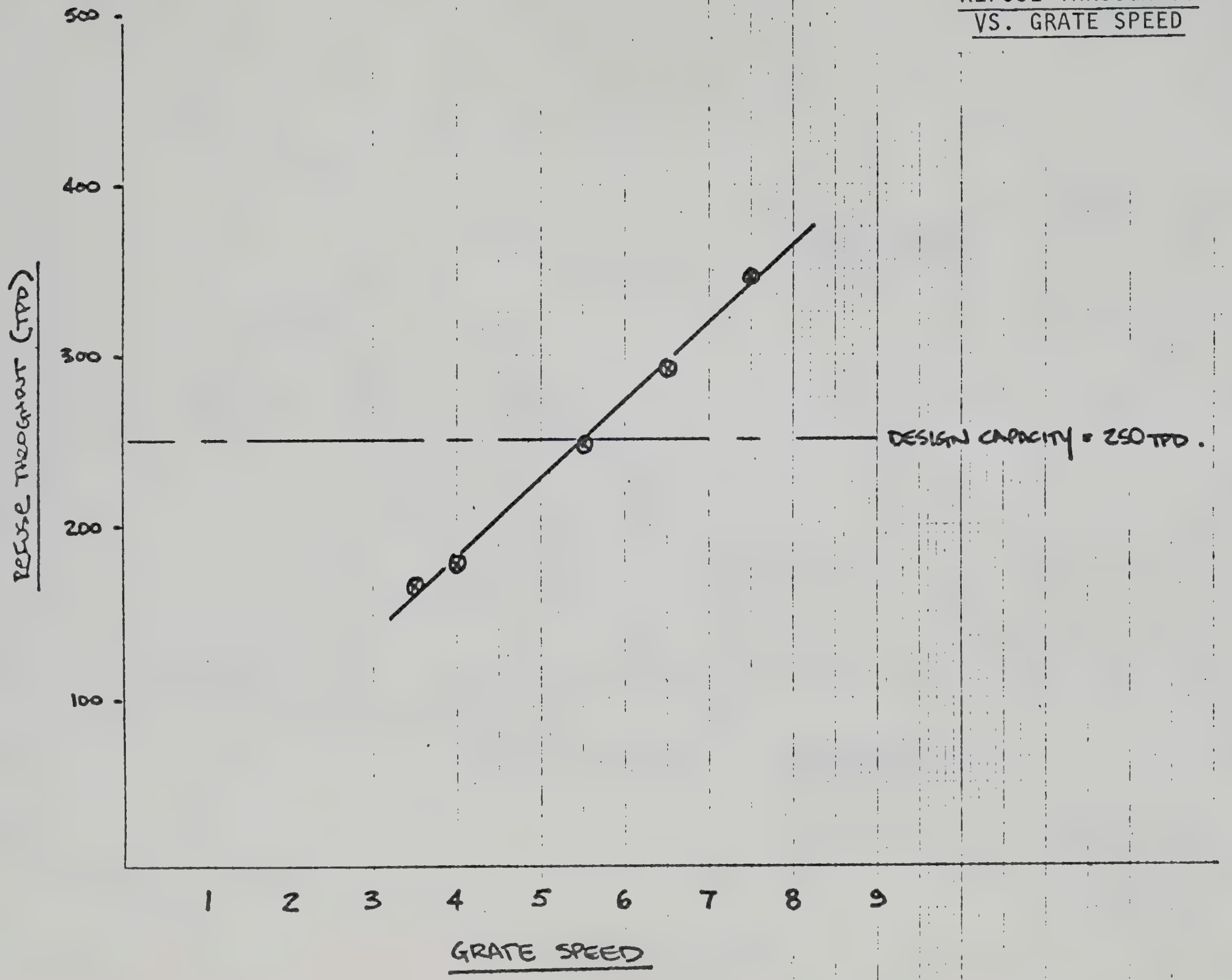


FIGURE B-2

FAN CALIBRATION CURVES

FURNACE #2

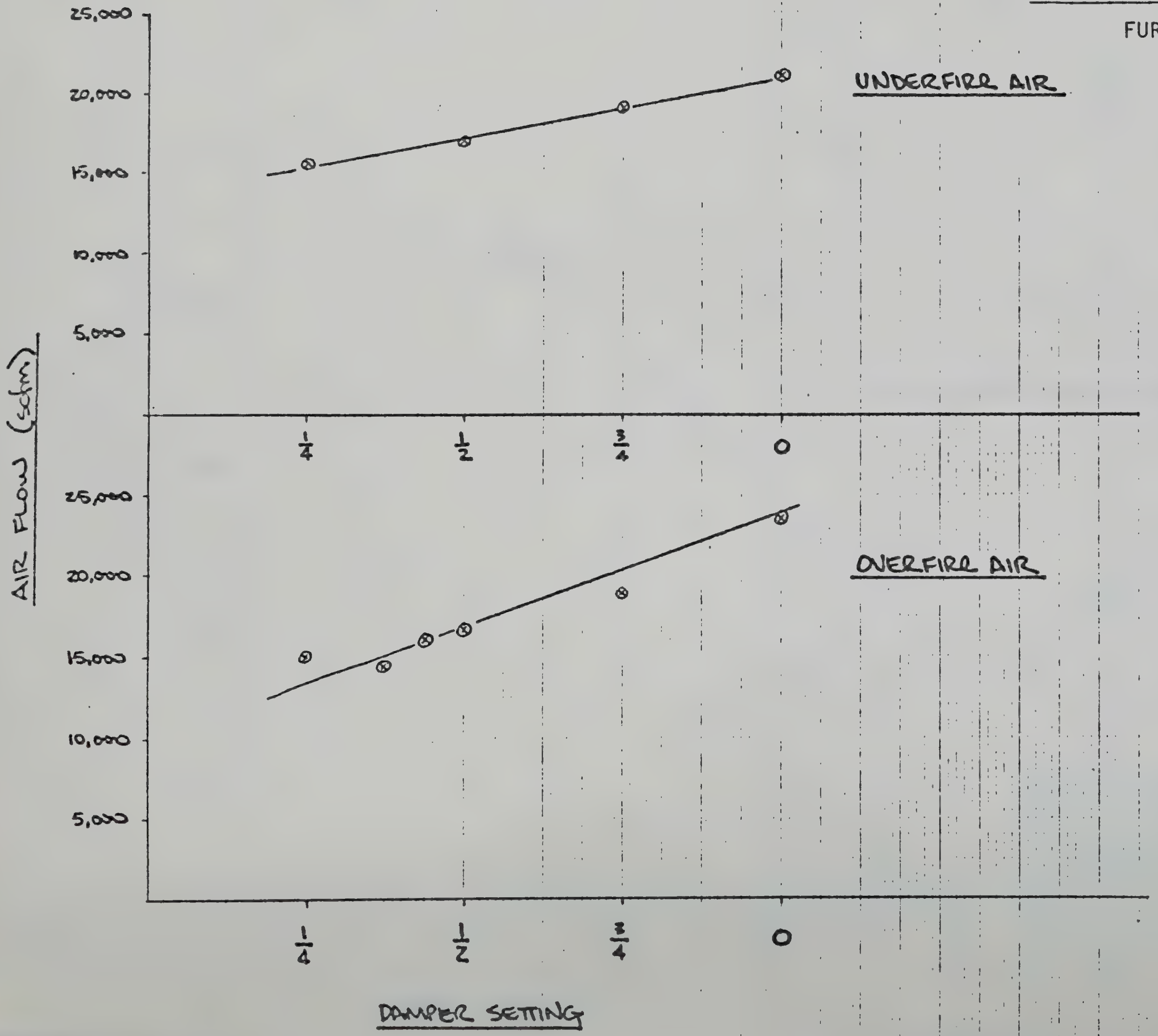
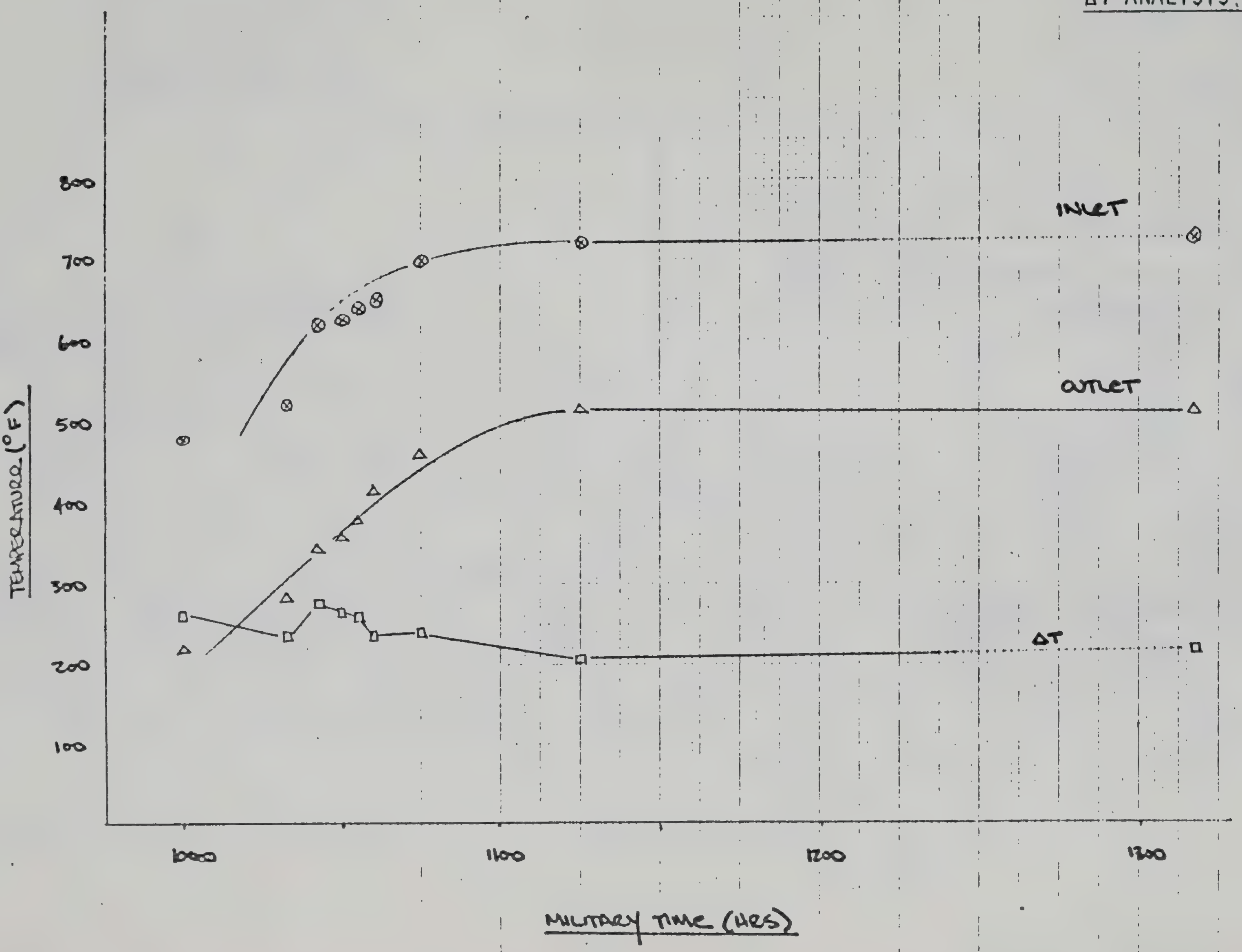
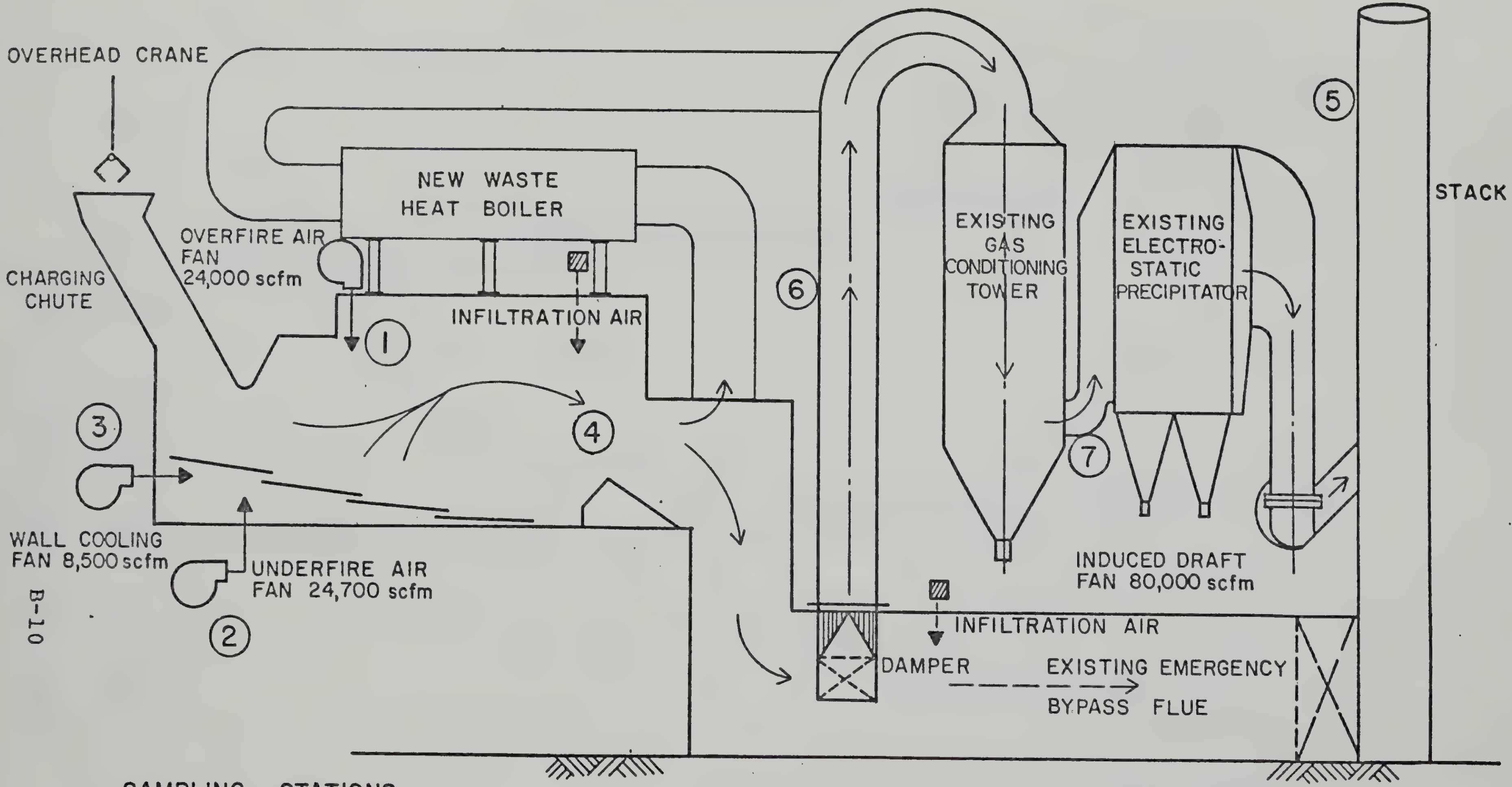


FIGURE B-3

GAS CONDITIONING TOWER

ΔT ANALYSIS.




OVERHEAD CRANE
CHARGING CHUTE
OVERFIRE AIR FAN 24,000 scfm
NEW WASTE HEAT BOILER
INFILTRATION AIR
WALL COOLING FAN 8,500 scfm
UNDERFIRE AIR FAN 24,700 scfm
EXISTING GAS CONDITIONING TOWER
EXISTING ELECTRO-STATIC PRECIPITATOR
STACK
INDUCED DRAFT FAN 80,000 scfm
INFILTRATION AIR
DAMPER
EXISTING EMERGENCY BYPASS FLUE
①
②
③
④
⑤
⑥
⑦

SAMPLING STATIONS

1. OVERFIRE AIR DUCT
2. UNDERFIRE AIR DUCT
3. WALL COOLING AIR DUCT
4. PORTS OVER DOG HOUSE
5. STACK PORTS
6. UPTAKE FLUE GCT
7. PORTS AFTER GCT

FIGURE B-4

INCINERATOR GAS FLOW TRAIN

TEST DESCRIPTION

1. VELOCITY TRAVERSE
2. VELOCITY TRAVERSE
3. VELOCITY TRAVERSE
4. TEMP. AND ORSAT
5. VELOCITY TRAVERSE AND ORSAT
6. VELOCITY TRAVERSE AND TEMP.
7. TEMP.

APPENDIX C

HEAT LOSS CALCULATIONS

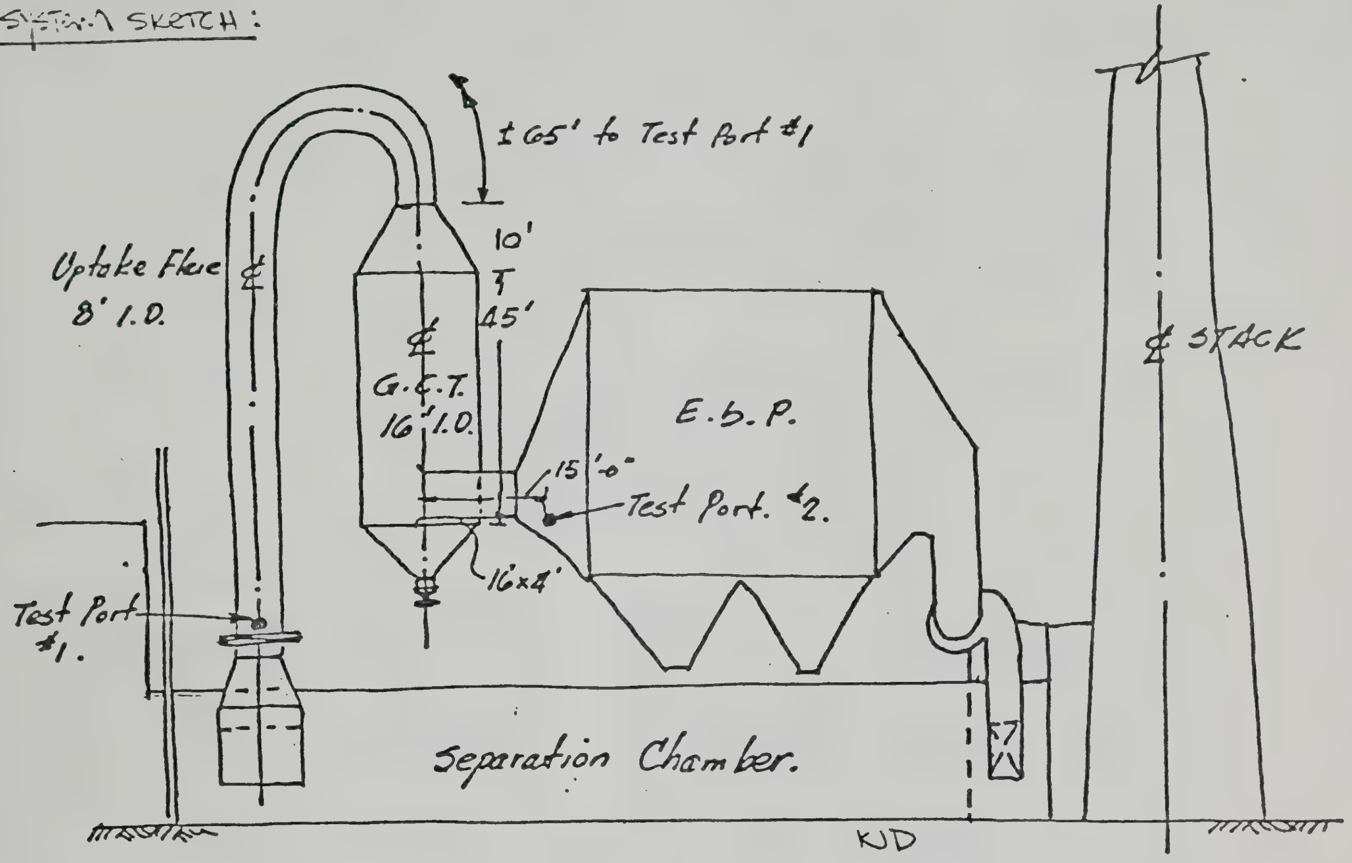
BY MAR DATE 22 JULY 81 JOB ________ SHEET 1 OF 3

CHKD BY ______ DATE ______ DEPT 3250 W.O. NO. 2147-01-01

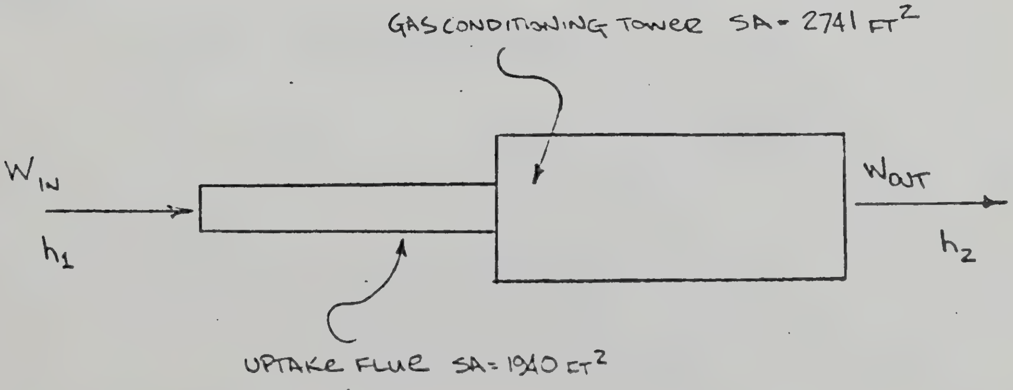
[illegible] SOUTHWEST BROOKLYN INCINERATOR

[illegible] HEAT TRANSFER CALCULATIONS - GAS CONDITIONING TOWER

SYSTEM SKETCH:



HEAT BALANCE:


GAS CONDITIONING TOWER SA = 2741 FT²
W_IN
h_1
W_OUT
h_2
UPTAKE FLUE SA = 1940 FT²

TOTAL AREA = 4681 FT²

BY MAB DATE 22 JULY 81 SHEET 2 OF 3

DATE DEPT 3200 W.O. NO. 2147-01-01

SOUTHWEST BROOKLYN INCINERATOR

SUBJECT HEAT TRANSFER CALCULATIONS

TEST CONDITIONS

FLOW RATE = 17,900 scfm

GAS DENSITY = 0.0764 #/CF

SPECIFIC HEAT @ 700°F = 0.253 BTU/lb-°F

$\Delta T = 224°F$

HEAT LOST BY FLUE GAS $= Wc_p\Delta T$

$= 17{,}900(0.0764)(0.253)(224)$

$= 77{,}502$ BTU/MIN

ASSUME HEAT IS LOST IN FLUE & TOWER IN PROPORTION TO THE SURFACE AREAS:

$$q_{flue} = {}^{1940}/_{4681}\ (77502) = 32{,}120 \text{ BTU/min}$$

$$q_{GCT} = 77{,}502 - 32{,}120 = 45{,}382 \text{ BTU/MIN}$$

COEFFICIENT OF HEAT TRANSFER

$$q_{GCT} = UA\,\Delta t_M$$

$$= UA\left[(\Delta t_{01}) - (\Delta t_{02})\right] \ln \Delta t_{01}/\Delta t_{02}$$

ASSUME $\Delta t_{GAS} = 50°F$

$\Delta t_{AIR} = 1°F$

$$U = 45{,}382(60)/2741\left[(50-1)/\ln(50/1)\right]$$

$$U_{GCT} = 79.3 \text{ BTUH}/\text{FT}^2\text{-}°\text{F}$$

SINCE HEAT FLOWS ARE PROPORTIONAL TO SURFACE AREAS, $U_{FLUE} = U_{GCT}$

BY MRG DATE 22 JULY 81 DIV ______ SHEET 3 OF 3

CHKD BY ______ DATE ______ DEPT 3200 W.O. NO. 2147 01 01

PROJECT SOUTHWEST BROOKLYN INCINERATOR

SUBJECT HEAT TRANSFER CALCULATIONS

ASSUME EXIT TEMPERATURE FROM BOILER = 450°F ; $\Delta T_{\text{ALLOWABLE}} = 50°\text{F}$, FLOW = 43,000 scfm

$$\text{TOTAL } q_{\text{ALLOWABLE}} = 43{,}000\,(0.0764)(0.253)(50)$$

$$= 41{,}553 \text{ BTU/min}$$

$$q_{\text{FLUE}} = {}^{1940}/_{4681}\,(41{,}553) = 17{,}223 \text{ BTU/min} < 32{,}120 \text{ BTU/MIN}$$

$\therefore$ INSULATION REQ'D

$$q_{\text{GCT}} = 24{,}335 \text{ BTU/min} < 45{,}382 \text{ BTU/min}$$

$\therefore$ INSULATION REQ'D

INSULATION REQUIREMENTS (MINERAL WOOL, k = 0.05 BTUH/FT-°F)

TOWER	FLUE
$q_{\text{GCT}} = {}^{0.05\,(2741)(449)}/_{x}$	$q_{\text{flue}} = {}^{0.05\,(1940)(449)}/_{x}$
$24{,}335\,(60) = {}^{0.05\,(2741)(449)}/_{x}$	$17{,}223\,(60) = {}^{0.05\,(1940)(449)}/_{x}$
$x = 0.04 \text{ FT}$	$x = 0.04 \text{ FT}$
$= \underline{\underline{0.51''}}$	$= \underline{\underline{0.51''}}$

These are minimum requiremets. The design and cost estimates reflect 4 in. insulation.

APPENDIX D

WET REFUSE CALCULATIONS AND TELEPHONE SURVEYS

WESTON

TO: NYCDOS FILE

CC: W. Chesner/E. Smith/A. Thau/K. Danz

FROM: M. Barbara

DATE: 21 April 1981

SUBJECT: BETTS AVENUE WASTE HEAT DATA

Data was collected from Betts Avenue records for the period between November 1976 - December 1979. This period of record was chosen for two reasons:

(1) Prior to the heating season of 1977, the waste heat boilers were operated rather indiscriminately, that is, with little regard for oil consumption.

(2) Data for 1980 was considered to be not applicable to the purpose of this study due to the lack of rainfall.

Amounts of steam generated, oil consumed and refuse burned were extracted from daily logbooks at Betts Avenue. Average ambient temperatures and rainfall statistics were compiled from NOAA monthly summaries for their weather station located at LaGuardia Airport (approximately 5 miles NNE of the incinerator). Data was tabulated on a daily basis for computational purposes.

As per normal operating conditions, excess steam produced in the waste heat boilers is condensed; however, no set pattern exists for the amount of excess steam produced. In order to remove some of this inherent variance in the data, a linear correlation was developed between the total amount of steam produced and the average daily ambient temperature over the period of record (Figure 1). Using this correlation, a theoretical steam production was calculated and utilized in subsequent calculations. Basically, the amount of oil consumed was converted into heating value (using 141,000 BTU/Gal @ 75% efficiency) and subtracted from the total steam production. The remainder, assumed to be the heat contributed by the burning refuse, was adjusted by the total refuse throughput to obtain the heating value of the refuse which was actually utilized. As a control, these data were also generated using actual daily steam production figures.

WESTON

BETTS AVENUE WASTE HEAT DATA

Average heat transferred was computed for dry days as well as against class intervals of rainfall events. Since operational experience indicates that morning rainfall is particularly significant, these occurrences were also analyzed separately.

From the initial analysis of the data, it was found that no significant correlations could be generated using the unsmoothed data and it was decided to proceed using the projected steam production correlation. A plot of percent BTU lost (as compared to dry refuse) versus rainfall is shown in Figure 2, attached. Note that the correlation coefficient for morning rainfall (0.71) events is slightly greater than the correlation obtained from the entire population (0.59).

In an attempt to further characterize the performance of the waste heat system, storm events of less than 1.0 inches were analyzed and plotted separately from events greater than 1.0 inches. The rationale behind this is that storms greater than 1.0 inches were usually of long duration and would not effect the refuse as significantly as a short, intense rain event. The result of this analysis is shown in Figure 3. Note the significant increase in all correlation coefficients, all indicating excellent fits.

MAB:ag
Attach.

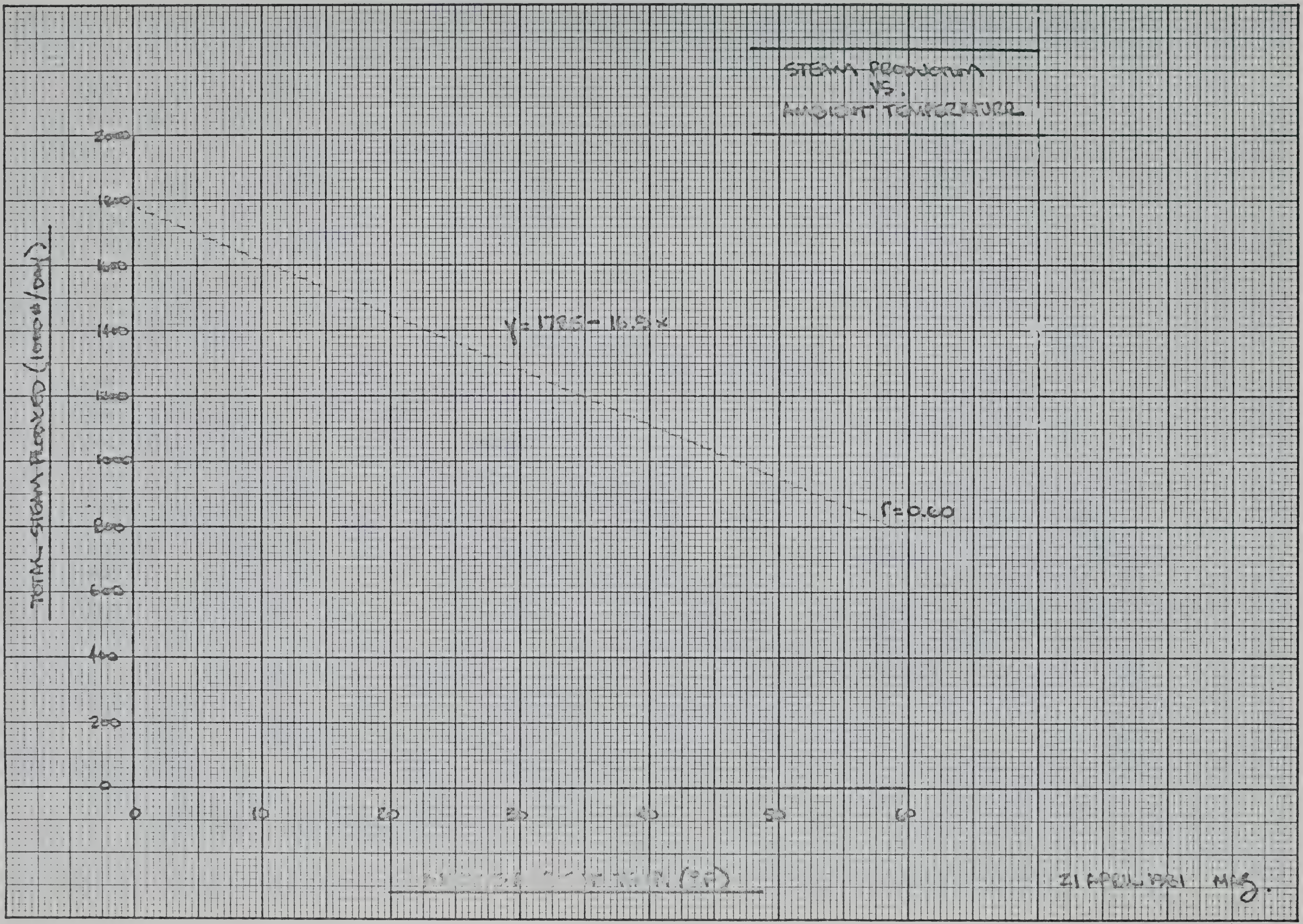

STEAM PRODUCTION
VS.
AMBIENT TEMPERATURE
TOTAL STEAM PRODUCED (1000#/DAY)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
AMBIENT TEMPERATURE (°F)
y = 1785 − 16.9x
r = 0.60
21 APRIL 1981 MHS.

FIGURE D-1

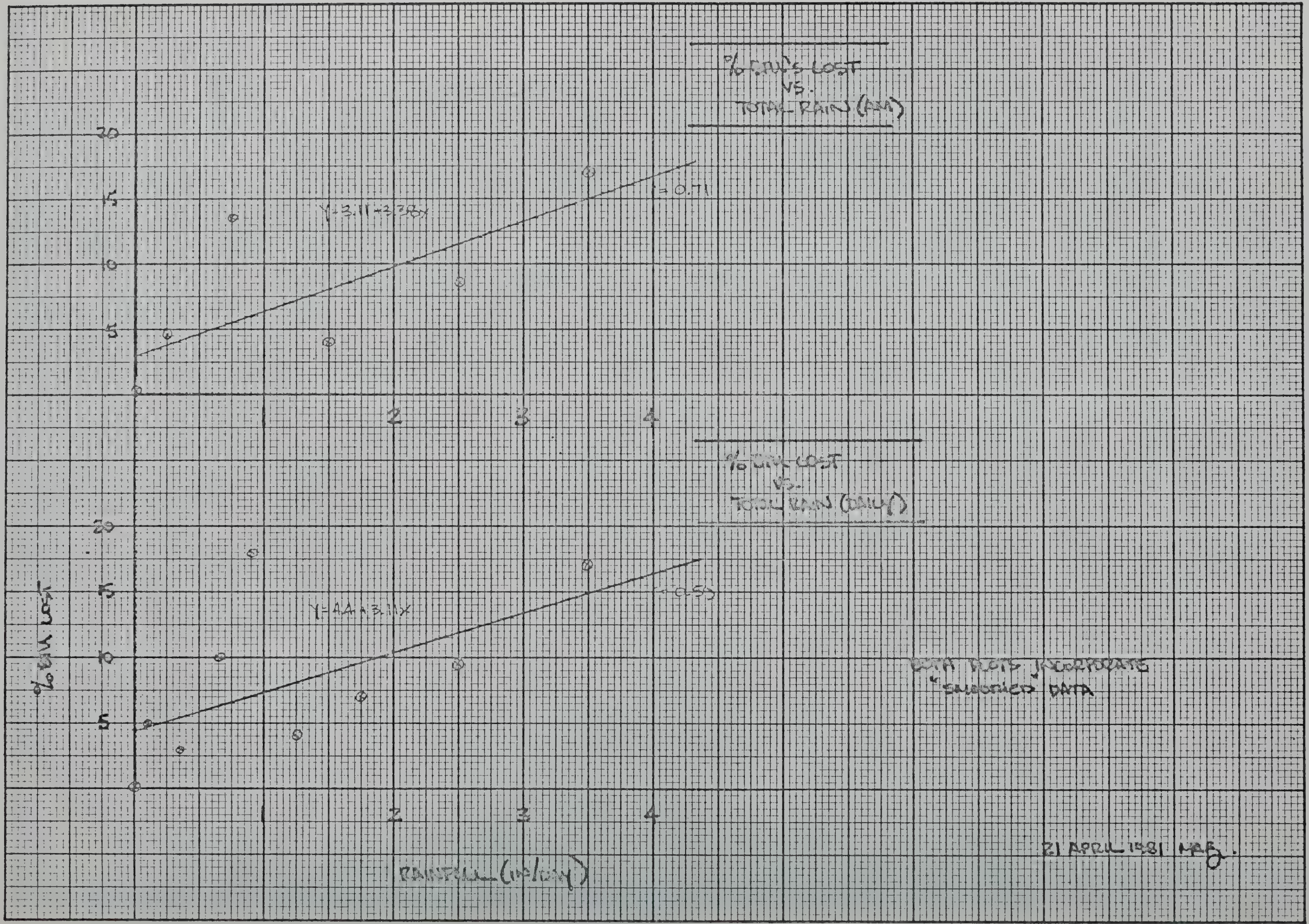
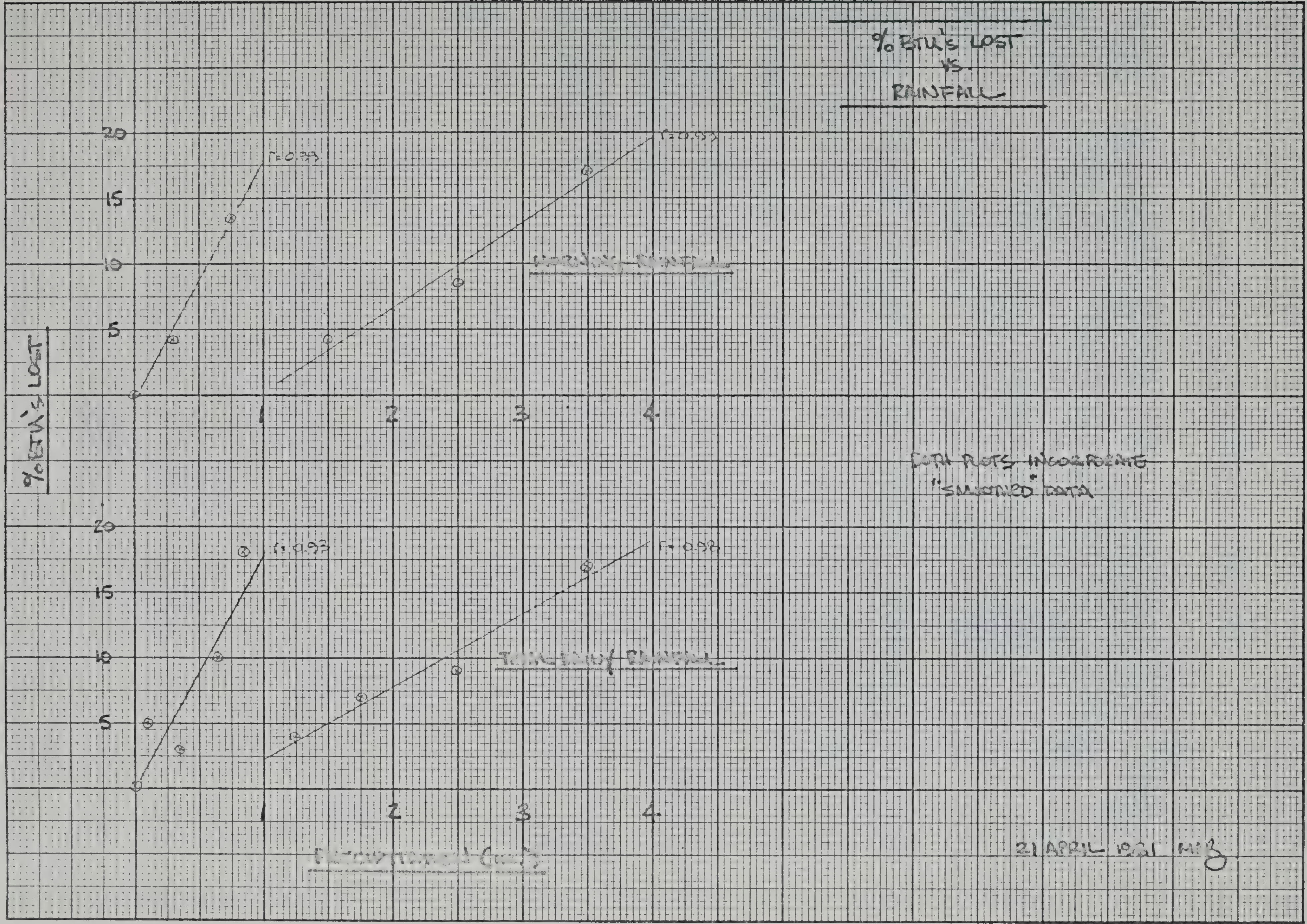
% DAY'S LOST
VS.
TOTAL RAIN (AM)
Y=3.11+3.38X
r=0.71
% DAY LOST
VS.
TOTAL RAIN (DAILY)
Y=4.4+3.11X
r=0.55
% DAY LOST
20
15
10
5
20
15
10
5
1
2
3
4
1
2
3
4
RAINFALL (IN/DAY)
DATA PLOTS INCORPORATE
"SMOOTHED" DATA
21 APRIL 1981 MAB.

FIGURE D-2


% BTU's LOST
vs.
RAINFALL
% BTU's LOST
20
15
10
5
1
2
3
4
r=0.99
r=0.97
HOURLY RAINFALL
r=0.93
r=0.98
TOTAL DAILY RAINFALL
PRECIPITATION (IN.)
BOTH PLOTS INCORPORATE
"SMOOTHED" DATA
21 APRIL 1981 MHB

BLACK &
VEATCH
CONSULTING
ENGINEERS

TELEPHONE MEMORANDUM

DATE May 26, 1981

(TO) ~~(FROM)~~ Bob Fitzgerald - Plant Chief Operating Engineer

TIME 11:30 AM ~~PM~~

COMPANY Chicago N.W. Incinerator

CC: KET

MCK

RECORDED BY Bill Stewart

PROJECT R. F. Weston - Feasibility Study NO. 9453

SUBJECT Burning Wet Refuse FILE NO.

I asked B. F. about burning of wet refuse. He said that the normal procedure after they get a 2-3 inch rain or a lot of snow is to stack the wet garbage to one side. After two or three days, the garbage compresses, most of the water drains out, and water is pumped out of the bottom of the pit. Apparently the garbage is then pretty dry and they go ahead and burn it without too much effect.

When they do burn wet refuse, the steam rate drops from 110,000 to about 60,000 pph. Procedure is to slow down rate of throughput to hold gas temperature.

One furnace had a drying grate installed with a steam preheater to increase air temperature by 100 F. B. F. said that it didn't work and have quit using it as the wet refuse - clogged up the grate/balled up on the grate. He said that, e.g., on a 40 F day, 140 F air wasn't drying out any garbage. (5-15 psi steam in preheater)

He said that rain wasn't big problem now that Chicago was putting covered 55 gal. drums in collection sites; rather snow was the main source of wet garbage.

dlw

BLACK &
VEATCH
CONSULTING
ENGINEERS

TELEPHONE MEMORANDUM

DATE May 29, 1981

(TO) ~~FROM~~ Jack Karper (717)255-3118

TIME 1:30 XXXX PM

COMPANY Harrisburg Incinerator, Harrisburg, PA

CC: KET

MCK

RECORDED BY Bill Stewart

PROJECT R. F. Weston-Feasibility Study NO.

SUBJECT Plant Operation FILE NO.

Availability: Overall about 80%. Operate 24 hrs/day, 365 days/yr.

Furnace Temperature: 1200-1400°F.

Steam Temperature: 500F.

Steam Press: 285 psig.

Waste: MSW + some commercial.

ESP Inlet Temperature: 450-475F.

% Excess Air: Unknown (14" ΔP on underfire air).

Waste Moisture Content: About 35%

Waste Heating Value: 3500-4000Btu, sometimes too dry and have to water down, as low as 2800.

Sell Steam: Yes, to city for district heating.

TPD: >600.

#blrs: 2, both operating.

Scheduled Maintenance: 45 days/yr/blr - Summer months

Problems: No particular problems. Have Martin grate, stoker/boiler system which he claims is better than others he has had experience with.

dlw

BLACK &
VEATCH
CONSULTING
ENGINEERS

TELEPHONE MEMORANDUM

DATE June 1, 1981

(TO) (FROM) Bob Fitzgerald (312)626-6750

TIME 2:00 XXX PM

COMPANY Chicago N.W. Incinerator

CC: KET

MCK

RECORDED BY Bill Stewart

PROJECT R. F. Weston-Feasibility Study NO.

SUBJECT Plant Operation FILE NO.

Availability: Worst outage was 48 hours in 5 years, 3 out of 4 boilers operate 24 hrs/day, 365 days/yr.

Furnace Temperature: 1600°F

Steam Temperature: 420°F

Steam Press: 275 psig

ESP Inlet Temperature: 700-800°F

ESP Outlet Temperature: 400-500°F

Preheater: UFA type on 1 boiler only, will be removed shortly due to problems of it plugging up (air type preheater).

Waste Moisture Content: 30%

Waste Heating Value: 4000 Btu

Sell Steam: Yes to Brach's candy

Steam Production: 110,000 lb/hr/boiler.

Net Refuse: Biggest problem is after large snowfalls (5"-6"-7"), snow melts in boiler. This requires the boiler to be slowed down, longer retention time.

Problems:
1. Cranes and conveyors, ash and dust in the air cause problems here.
2. Collectors sometimes pick up large steel objects (e.g., engine blocks), the operators do their best to randomly sort loads.
e. Collectors scoop up large amounts of snow and this is mixed with refuse.

dlw

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ENGINEERS

TELEPHONE MEMORANDUM

DATE June 2, 1981

(TO) ~~(FROM)~~ Dan Madigan (617)233-7600

TIME 9:00 AM ~~PM~~

COMPANY Saugus, Mass., Incinerator-Wheelabrator Frye

CC: KET

MCK

RECORDED BY Bill Stewart

PROJECT R. F. Weston-Feasibility Study NO.

SUBJECT Plant Operation FILE NO.

Availability: 92%.

Furnace Temperature: 3100°F at grate, 1600°F top.

Steam Temperature: 850°F.

Steam Press: 650 psig.

ESP Inlet Temperature: 435°F.

Preheating Air: No.

Moisture Content of Refuse: 25%.

Heating Value: 4500 Btu.

Wet Refuse: No problem - very large furnace, with a preheating area for refuse.

Residence Time: 55-65 min.

Sell Steam: Yes.

Steam Production: 370,000 pph.

#Blrs. Operating: 2 - 185,000 pph. Each.

Problems: The only problems they have is when they attempt to burn large tree trunks.

dlw

BLACK &
VEATCH
CONSULTING
ENGINEERS

TELEPHONE MEMORANDUM

DATE June 25, 1981

(TO) (FROM) Dick Seelinger (312) 391-2000

TIME 10:00 AM ~~PM~~

COMPANY UOP

CC: KET

MJE

WES

EOS

RECORDED BY M. Knatz

PROJECT Weston/PASNY NO. 9453

SUBJECT Air Preheat FILE NO.

1. UOP includes air preheat on all their jobs. There are 2 reasons:

   - Drying wet refuse is the primary purpose.
   - When dry refuse is burned an estimated 4 per cent increase in steam flow can be achieved.

2. The statements from the Chicago plant are true but are not due to preheat problems. Chicago designed and installed their own preheater using finned tubes (12 fins per inch). Underfire air is drawn from the pit and pulls dust and small scraps into the heater. The heater clogs and the trash balls up on the grate due to poor air distribution. UOP uses 4 fins per inch and spaces the tubes so that they can be water cleaned easily. Dick felt that cleaning would not be necessary more than once a year.

3. The Harrisburg incinerator does not need preheat. They burn mostly dry industrial refuse. Dick estimated that the moisture content at Harrisburg is on the order of 20 per cent not 35 per cent.

4. Both the Chicago and Harrisburg units were designed with Martin stokers.

5. UOP preheats the air to 250 F. UOP uses 85 per cent excess air as the design on their units.

dlw

APPENDIX E

SYSTEM AVAILABILITY CALCULATIONS

APPENDIX E

SYSTEM AVAILABILITY CALCULATIONS

The availability, or the probability that the system will be operational at a future instant in time, can be calculated using the following equation (referring to Figure 4-2):

Where:

$$P = \frac{n!}{(n-r)!\ r!} (A_i^r \overline{A}_i^{n-r}) (A_t) (I-\overline{A}_p^2) (I-\overline{A}_{cp}^2) (I-\overline{A}_{cw}^2) (A_c) (A_{ct})$$

n = Number of furnaces and waste heat boilers.

r = Number of furnaces and waste heat boilers available.

A_i = Probability that an individual furnace and waste heat boiler is not available.

$\overline{A}_i$ = Probability that an individual furnace and waste heat boiler is not available.

A_t = Probability that the turbine is available.

$\overline{A}_p$ = Probability that an individual feed pump is not available.

$\overline{A}_{cp}$ = Probability that an individual condensate pump is not available.

$\overline{A}_{cw}$ = Probability that an individual circulating water pump is not available.

A_c = Probability that the condenser is available.

A_{ct} = Probability that the cooling tower is available.

These probabilities are summarized in Table E-1. The availability calculation assumes that the average annual availability of the furnace follows a bionomial distribution where the probability that the furnace is up (A_i) is 0.75, and the probability that it is down is ($\overline{A}_i$) is 0.25.

The probability of zero energy output is the sum of the unavailable probabilities of each component of Figure 4-2 (i.e., probability that zero furnaces are available + probability that the turbine is unavailable + etc.).

Table E-1

Component Availabilities

	n	r	A_i	$\bar{A}_i$	A_t	$\bar{A}_p$	$\bar{A}_{cp}$	$\bar{A}_{cw}$	A_c	A_{ct}
0% System Availability	4	0	0.75	0.25	0.93	0.003	0.003	0.001	0.974	0.999
25% System Availability	4	1	0.75	0.25	0.93	0.003	0.003	0.001	0.974	0.999
50% System Availability	4	2	0.75	0.25	0.93	0.003	0.003	0.001	0.974	0.999
75% System Availability	4	3	0.75	0.25	0.93	0.003	0.003	0.001	0.974	0.999
100% System Availability	4	4	0.75	0.25	0.93	0.003	0.003	0.001	0.974	0.999

Table E-2

Incinerator Refuse Throughput

% Capacity		% of Time	Hours/ year	Incinerator hours
0%	$P = \frac{4!}{(4-0)!0!}(0.75)^{0}(0.25)^{4-0} =$	0.4%	35	0
25%	$P = \frac{4!}{(4-1)!1!}(0.75)^{1}(0.25)^{4-1} =$	4.7%	412	412
50%	$P = \frac{4!}{(4-2)!2!}(0.75)^{2}(0.25)^{4-2} =$	21.1%	1,848	3,696
75%	$P = \frac{4!}{(4-3)!3!}(0.75)^{3}(0.25)^{4-3} =$	42.2%	3,697	11,091
100%	$P = \frac{4!}{(4-4)!4!}(0.75)^{4}(0.25)^{4-4} =$	31.6%	2,768	11,072
		100%	8,760 hrs	26,271 hrs

26,271 hrs x 20,833 lbs/hr/2,000 lbs/ton = 273,656

say 274,000 tons/yr

APPENDIX F

CASH FLOW ANALYSIS OIL REPLACEMENT

Table F-1

Cash Flow Forecast -- Electricity Generation Only
(Oil Replacement in 1981 $)

Year	Debt Payments $1,000	O&M Costs $1,000	Total Annual Costs $1,000	Elec-tricity Rate $/kWh	Elec-tricity Revenue $1,000	Steam Revenues $1,000	Total Annual Revenues $1,000	Difference In Revenues Minus Cost $1,000
1986.	6914.	2222.	9136.	0.10264	9624.	0.0	9624.	488.
1987.	6914.	2400.	9314.	0.11300	10595.	0.0	10595.	1281.
1988.	6914.	2592.	9506.	0.12441	11665.	0.0	11665.	2159.
1989.	6914.	2799.	9713.	0.13698	12844.	0.0	12844.	3131.
1990.	6914.	3023.	9937.	0.15082	14141.	0.0	14141.	4204.
1991.	6914.	3265.	10179.	0.16605	15569.	0.0	15569.	5390.
1992.	6914.	3526.	10440.	0.18282	17142.	0.0	17142.	6702.
1993.	6914.	3808.	10722.	0.20128	18873.	0.0	18873.	8150.
1994.	9929.	4113.	14042.	0.22161	20779.	0.0	20779.	6737.
1995.	9929.	4442.	14371.	0.24399	22877.	0.0	22877.	8506.
1996.	9929.	4797.	14726.	0.26864	25188.	0.0	25188.	10462.
1997.	9929.	5181.	15110.	0.29577	27732.	0.0	27732.	12622.
1998.	10809.	5595.	16404.	0.32564	30533.	0.0	30533.	14129.
1999.	10809.	6043.	16852.	0.35854	33618.	0.0	33618.	16766.
2000.	10809.	6526.	17335.	0.39475	37013.	0.0	37013.	19677.
2001.	10809.	7049.	17858.	0.43461	40750.	0.0	40750.	22893.
2002.	10809.	7612.	18421.	0.47851	44866.	0.0	44866.	26445.
2003.	10809.	8221.	19030.	0.52684	49398.	0.0	49398.	30368.
2004.	10809.	8879.	19688.	0.58005	54387.	0.0	54387.	34699.
2005.	10809.	9589.	20398.	0.63863	59880.	0.0	59880.	39481.
2006.	10809.	10357.	21166.	0.70314	65928.	0.0	65928.	44763.
2007.	2933.	11185.	14118.	0.77416	72587.	0.0	72587.	58469.
2008.	2933.	12080.	15013.	0.85234	79918.	0.0	79918.	64905.
2009.	2933.	13046.	15979.	0.93840	87987.	0.0	87987.	72008.
2010.	2933.	14090.	17023.	1.03318	96874.	0.0	96874.	79851.

APPENDIX G

RESIDUE TESTING PROGRAM

APPENDIX G

TECHNICAL PROPOSAL FOR TESTING PROGRAM

The technical proposal is divided into two sections:

I. TECHNICAL OVERVIEW
II. SCHEDULE

I. TECHNICAL OVERVIEW

The laboratory test program involves three basic tasks:

1. Sampling of Residue
2. Residue Characterization
3. Asphalt Mix Design

Task 1: Sampling of Residue

An initial visit to the plant site will be required to develop an agreed upon technique for obtaining residue samples. Residue samples from the plant in question will be collected over a one-month time period to establish the range of physical and chemical characteristics of the residue in relation to variable operating conditions at the plant. It is proposed that two daily grab samples be obtained for a total of ten days over the sampling period. Each sample will be taken during a time period when the plant is operating in a consistent manner, typical of the day's operation. A minimum sample size sufficient to fill a 5-gallon container is recommended. During this time, samples will be deliberately taken on one or two rainy days in order to determine what, if any, change in residue quality can be detected during rainy periods. It is, therefore, expected that approximately twenty residue samples will be collected and included in the characterization testing program.

Task 2: Residue Characterization

Once the samples have been obtained, each will be characterized in order to determine the following properties:

- Particle Size Distribution
- Unit Weight
- Moisture Content
- Loss On Ignition
- Presence Of Organics

In addition, each sample will be visually separated and classified into five basic categories: glass, ferrous metal, non-ferrous metal, minerals and ash, and combustible and organics. Figure 1 shows a sequence recommended for characterization testing of each residue sample. The results of the characterization tests for various samples will be compared with each other to determine average and range of properties and to establish a relationship between sample properties and plant operating conditions.

Task 3: Asphalt Mix Design

Prior to developing an asphalt mix design using incinerator residue, it will first be necessary to obtain and review pertinent D.O.T. paving specifications and to meet with appropriate D.O.T. officials and decide the type of paving mix and aggregate to be considered for use with incinerator residue.

Following characterization, asphalt mix design tests will be performed in the laboratory using the Marshall mix design method (ASTM D1559) for wearing course test specimens. A mix design will be developed that will satisfy the Marshall stability, flow and air voids criteria. The retained strength of the design mix will be evaluated by means of the immersion-compression test (ASTM D1075). This proposal is based on performing tests with a progressive increase in the percentage of incinerator residue constituting the total aggregate in a given asphalt mix. A total of eight different levels of residue addition, ranging from 10 to 80 percent by total weight of aggregate in the mix, will be analyzed. In addition, two other asphalt mix design tests will be performed using residue that has been processed to remove ferrous metal. The ferrous free residue will be evaluated at the optimum residue percentages determined from the Marshall tests.

A summary report will be prepared including not only the test results, but also providing conclusions resulting from an analysis of these results.

II. SCHEDULE

It is anticipated that the characterization program can be completed in two months, including a one-month sampling period. An additional six weeks will be required for the asphalt testing, with two weeks further for preparation of a written report. Therefore, a total elapsed time of four months will be needed in order to fully complete the test program.

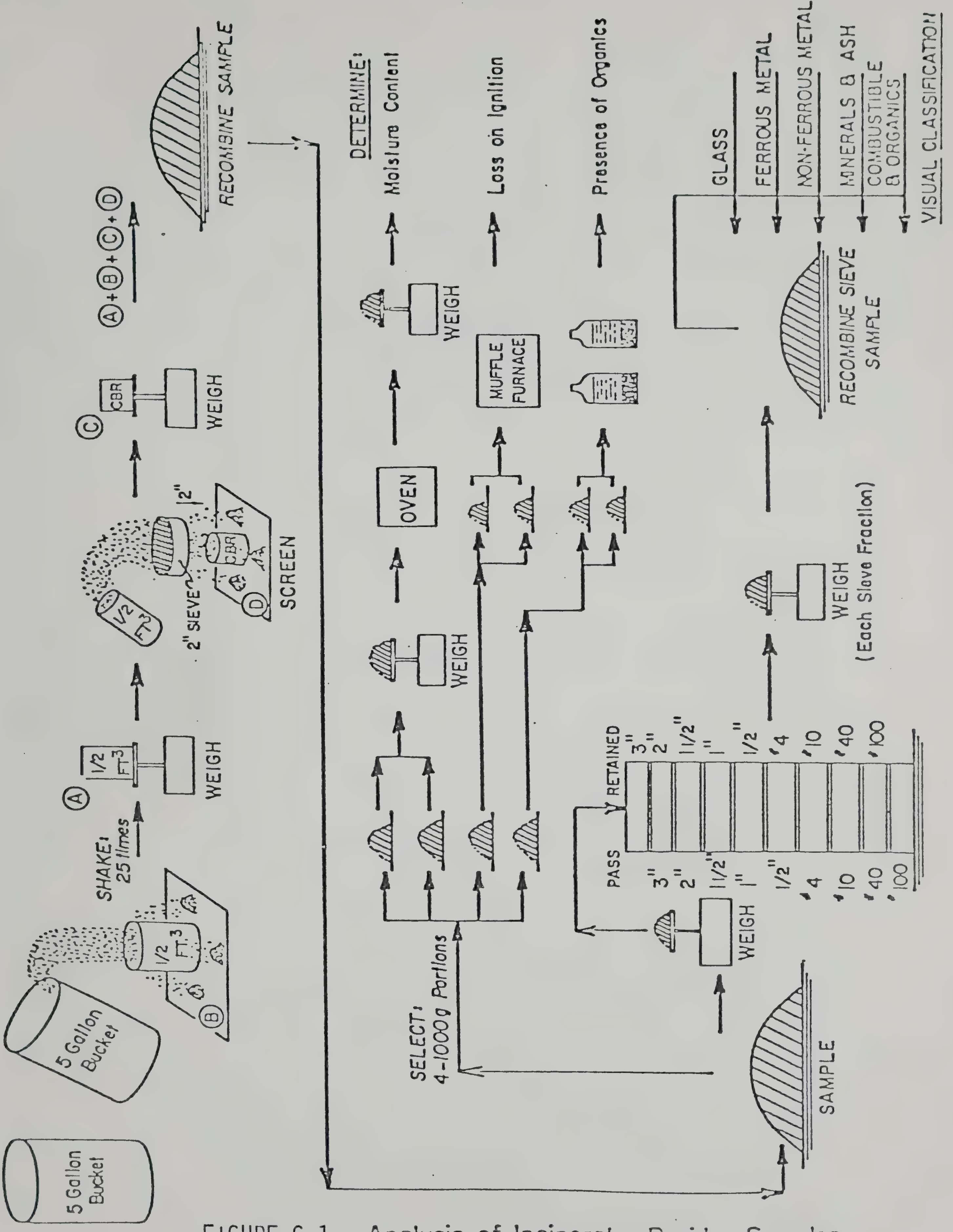

FIGURE G-1: Analysis of Incinerator Residue Samples

APPENDIX H

ECONOMIC CRITERIA

POWER AUTHORITY OF THE STATE OF NEW YORK
10 COLUMBUS CIRCLE NEW YORK, N. Y. 10019
(212) 397-6200

TRUSTEES
JOHN S. DYSON
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LEROY W. SINCLAIR
SENIOR VICE PRESIDENT & CHIEF FINANCIAL OFFICER
THOMAS R. FREY
SENIOR VICE PRESIDENT & GENERAL COUNSEL

July 20, 1982

Mr. Michael Barbara
Environmental Resources Management
(ERM-Northeast)
80 Sunnyside Boulevard
Suite 305
Plainview NY 11803

Subject: Feasibility Study for Resource Recovery
at Southwest Brooklyn Incinerator
Updated Criteria for Economic Evaluation

Dear Mike;

As discussed at our meeting of June 30, 1982, we have updated the criteria for the subject feasibility study. The following parameters replace the data in our letters of July 6, 1981 and August 31, 1981, and should be used in the study:

1. Economic Criteria

   a. Start of construction of the once-through cooling alternative* is December 1984 and of the cooling tower alternatives is June 1984.(1) The length of the construction period is part of the study and should be estimated by the A-E.(2) The plant life is expected to be 25 years. The waste heat boilers will be replaced to a large extent (about 80%) after 12½ years of operation. (This was estimated by the A-E and is based on information gathered in field visits.)

   b. The revamping of the facility will be financed with bonds to be issued for 28 years at 10% interest. (This assumes a 26 month construction and start-up period, as estimated by the A-E).

      Debt service coverage, 15%.

      Bond reserve requirement will be 10% of total bond issue to be reinvested at 11.5% annually.

      Bond financing cost will be 2% of total bond issue.

---

* No cash flow forecasts will be developed for the once-through cooling alternative.

Start-up costs, equal to half-a-year O&M, will be included in the capital cost.

Revenues during half-a-year of start-up and commissioning of the plant will be used to offset total costs in the initial contract years in our amount to be determined by the Authority (AR Fund).

c. Escalation rate of 10% for equipment and site materials and of 8% for O&M.

d. Oil cost;*

Year	Cost $/10^6BTU	Esc.
1982	5.74	11.7%
1985	8.00	9.5%
1990	12.57	9.0%
1995	19.36	8.7%
2000	29.40	-

e. Interest during construction (IDC): 10%

f. Present worth discount rate: 10%

g. Operation and Improvement reserve: Not to be included in cash flow analysis.

h. Indirect Costs:

- Design, engineering and construction management - 15% on total direct
- Owner's costs will not be included in the cash flow analyses

i. Contingency equal to 15% on total direct and indirects

j. Project's year of first principal payment: 9

- You can use for the economic calculations the computer program for T159, which we gave you.

2. Load Model

a. Each incinerator is ejected to be available 75% of the year (based on previous Department of Sanitation experience).

b. Projected operation: 7 days per week, 24 hours per day.

---

*Based on February 1982 ICF Report for NY Power Pool

c. Expected electricity rates:**

Years	Mills/Kwh	Year	Mills/Kwh	Year	Mills/Kwh	Year	Mills/Kwh
1986	77.00	1992	130.26	1998	269.31	2004	432.30
1987	81.64	1993	138.77	1999	299.03	2005	471.27
1988	95.37	1994	162.33	2000	327.82	2006	501.18
1989	104.82	1995	180.13	2001	354.06	2007	533.40
1990	112.60	1996	199.89	2002	383.43	2008	568.07
1991	123.93	1997	236.97	2003	394.48	2009	604.99
						2010	644.31

** Based on June 1982 NYPP statewide avoided costs for currently projected ICF fuel price increase.

The avoided cost is the cost of fuel and incremental maintenance of existing thermal plants in New York State which would not be incurred if the Arthur Kill Plant is built, but would be incurred if it is not built.

The projected statewide avoided costs were calculated assuming a NYPP expansion plan that only included units currently under construction and excluded all unlicensed pumped hydro, small hydro and resource recovery units. Arthur Kill and all other planned coal units, coal conversions and coal units required to maintain the minimum 22% reserve are assumed to be 12.3 billion kwhrs/year between 1988 and 1996, and 6 billion kwhrs/year thereafter. Ontario Hydro imports and sales to other regions such as New England and PJM were assumed to be zero.

d. Expected steam rates:

To be calculated by including replacement of fuel oil at 85% combustion efficiency and maintenance costs for the steam loops. Expected maintenance costs for the steam distribution portion of the project (in 1981 $) are:

- Full steam loop - 0.86 $/$10^6$ Btu
- Partial steam loop - 0.41 $/$10^6$ Btu

e. Makeup water cost: $1.5 per 1000 gallons in 1980 to be escalated at 8%.

The study is to include cash flow forecasts for the project alternatives. Each cash flow forecast shall comprise the following columns: Debt Payments, O&M Costs, Total Annual Costs, Electricity Rates, Electricity Revenues, Steam Revenues, Total Annual Revenues, Difference of Revenues - Costs.

NOTES: 1. The start of construction date is predicated on the following target dates of the projects:

- Completion date of the study: End of July, 1982
- Contract negotiations with City completed by end of December, 1982.
- Detailed design and equipment specifications: 1 year
- Bid preparation and procurement: 1 year

2. In accordance with the minutes of the November 5, 1980 meeting, Black & Veatch and the City will evaluate any potential modification to permit requirements with appropriate regulatory agencies (see point 4 of the minutes). The cost and length to be added to the data specified in 1.(a) and 1.(h).

If you have any questions or problems, please do not hesitate to call me.

This letter shall be included, for reference, in the final report of the projects.

Sincerely,

Albert Thau
R&D Engineer

AT/vlf

cc: G. I. Stillman
R. Heyrman
T. Hamill
D. Kau
H. Szarpanski - NYC Department of Sanitation
W. Chesner - Engineering Consultants and Ass.
E. O. Smith - Black & Veatch
K. Trout - Black & Veatch

APPENDIX I

REVISED BOND ISSUE PROGRAM INPUT AND OUTPUT

BLACK & VEATCH
CONSULTING ENGINEERS

Owner
Plant Unit
Project No. File No.
Title

Computed By
Date 6/21 1982
Checked By
Date 19
Page 1 of

DO NOT WRITE IN THIS SPACE

INPUT DATA, PROG. 1
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6/21/82

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         1.       09
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       0.08       11
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         6.       13
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         0.       18
      0.059       19
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         0.       24
         0.       25
         0.       26
         0.       27
         0.       28
         0.       29
         0.       30
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         0.       32
         0.       33
         0.       34
         0.       35
         0.       36
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         0.       38
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ELECT GEN. ONLY
6/21/82

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       182.      12
         6.      13
       0.02      14
       0.05      15
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        0.1      17
         0.      18
      0.059      19
        26.      20
       0.15      21
         1.      22
         0.      23
         0.      24
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BLACK & VEATCH
CONSULTING ENGINEERS

Owner ______
Plant ______ Unit ______
Project No. ______ File No. ______
Title ______

Computed By ______
Date 6/21 19 82
Checked By ______
Date ______ 19 ______
Page 2 of ______

DO NOT WRITE IN THIS SPACE

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     0.1976        53
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6/21/82

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       0.08        11
       182.        12
         6.        13
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INPUT DATA PROG 1
ELECT GEN, BOILER REP
6/21/82

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         0.        00
   6700000.        01
     0.0575        02
        0.1        03
         0.        04
         0.        05
        60.        06
         2.        07
         0.        08
         1.        09
    466000.        10
       0.08        11
        30.        12
         1.        13
       0.02        14
       0.05        15
         1.        16
        0.1        17
         0.        18
      0.059        19
         8.        20
       0.15        21
         1.        22
         0.        23
         0.        24
         0.        25
         0.        26
         0.        27
         0.        28
         0.        29
         0.        30
         0.        31
         0.        32
         0.        33
         0.        34
         0.        35
         0.        36
         0.        37
         0.        38
         0.        39
         0.        40
        0.2        41
        0.3        42
        0.4        43
        0.5        44
        0.6        45
```

Owner

Plant Unit

Project No. File No.

Title

Computed By

Date 6/21 1982

Checked By

Date 19

Page 3 of

DO NOT WRITE IN THIS SPACE

```
           0.7    46              1.    13
           0.8    47            0.02    14
           0.9    48            0.05    15
            1.    49              1.    16
            0.    50             0.1    17
        0.0663    51              0.    18
        0.1295    52           0.059    19
        0.1976    53              8.    20
        0.2558    54            0.15    21
        0.3347    55              1.    22
        0.4531    56              0.    23
        0.5917    57              0.    24
        0.7958    58              0.    25
            1.    59              1.    26
                         6792213.774    27
                         6684166.702    28
                                 60.    29
                                  1.    30
                                  1.    31
                         1.000261158    32
                          1.00030639    33
                                 30.    34
   1727338.613                    2.    35
   5064875.161                    0.    36
                                 49.    37
                                  0.    38
                                 59.    39
   6792213.774                    0.    40
                                 0.2    41
                                 0.3    42
   1711536.584                   0.4    43
   4972630.117                   0.5    44
                                 0.6    45
                                 0.7    46
                                 0.8    47
   6684166.702                   0.9    48
                                  1.    49
                                  0.    50
                              0.0663    51
      6700000.    01          0.1295    52
        0.0575    02          0.1976    53
           0.1    03          0.2558    54
            0.    04          0.3347    55
            0.    05          0.4531    56
           60.    06          0.5917    57
            2.    07          0.7958    58
            0.    08              1.    59
            1.    09
       466000.    10
          0.08    11
           30.    12
```

OUTPUT DATA, PROG 1
ELECT GEN, BOILER REP
6/21/82

Owner
Plant Unit
Project No. File No.
Title

Computed By
Date 6/21 19 82
Checked By
Date 19
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DO NOT WRITE IN THIS SPACE

OUTPUT DATA, PROG 2
ELECT. GEN, BOILER REP
6/21/82

```
                                    170492.5947        41
                                    355495.1974        42
                                    852462.9734        43
                                    100590.6309        44
                                    879741.7886        45
                                    2637892.346        46
     6700000.          01           3033576.198        47
       0.0575          02           2932985.567        48
          0.1          03           879741.7886        49
           0.          04           2932985.567        50
           0.          05                    0.        51
          60.          06                    0.        52
           2.          07                    0.        53
           0.          08                    0.        54
           1.          09                    0.        55
      466000.          10                    0.        56
         0.08          11                    0.        57
          30.          12                    0.        58
           1.          13                    0.        59
         0.02          14
         0.05          15
           1.          16
          0.1          17
           0.          18
        0.059          19
           8.          20
         0.15          21
           1.          22
           0.          23
           0.          24
           0.          25
           1.          26
  6792213.774          27
  6684166.702          28
   1.00030639          29
           1.          30
  .0417021277          31
  .3094436273          32
  1.000210874          33
          30.          34
          60.          35
          90.          36
         1.15          37
           0.          38
  462012.2668          39
  8524629.734          40
```

BLACK & VEATCH
CONSULTING ENGINEERS

Owner ____________________
Plant ____________________ Unit ____________________
Project No. __________ File No. ____________________
Title ____________________

Computed By ____________________
Date 6/22 19 82
Checked By ____________________
Date __________ 19 ____
Page 1 of 2

DO NOT WRITE IN THIS SPACE

INPUT DATA, PROG. 1
PARTIAL STEAM LOOP
6/22/82

```
                                   0.7     46    1172582.359
                                   0.8     47    2022585.301
                                   0.9     48    2034383.944
                                   1.      49    2065558.328
          0.        00             0.      50    1942772.207
   44768000.        01             0.063   51    1760428.836
          0.0575    02             0.1295  52    2070644.463
          0.1       03             0.1976  53    2380003.822
       1004.        04             0.2558  54    3090655.414
          0.        05             0.3347  55    3561701.372
        578.        06             0.4531  56    3981579.048
         19.        07             0.5917  57    4157901.352
          0.        08             0.7958  58    5721987.349
          1.        09             1.      59    6106032.418
     809000.        10                           6100327.417
          0.08      11                           6092239.738
        182.        12
```

OUTPUT DATA, PROG. 1
PARTIAL STEAM LOOP
6/22/82

```
          6.        13
          0.02      14
          0.05      15                            57147471.4
          4.        16
          0.1       17    972372.7248
          0.        18    980127.6839
          0.059     19    987944.4912            44768000.        01
         26.        20   1217117.792                    0.0575    02
          0.15      21   2119060.768                    0.1       03
          1.        22   2151378.364                 1004.        04
          0.        23   2204797.223                    0.        05
          0.        24   2093150.158                  578.        06
          0.        25   1914451.205                   19.        07
          0.        26   2272891.237                    0.        08
          0.        27   2636926.931                    1.        09
          0.        28   3456354.992               809000.        10
          0.        29   4020430.607                    0.08      11
          0.        30   4536466.647                  182.        12
          0.        31   4781717.052                    6.        13
          0.        32   6642076.891                    0.02      14
          0.        33   7154238.655                    0.05      15
          0.        34   7214475.723                    4.        16
          0.        35   7272369.433                    0.1       17
          0.        36                                  0.        18
          0.        37                                  0.059     19
          0.        38                                 26.        20
          0.        39  64628348.63                     0.15      21
          0.        40                                  1.        22
          0.2       41                                  0.        23
          0.3       42                                  0.        24
          0.4       43    963553.0029                   0.        25
          0.5       44    962028.7044                   1.        26
          0.6       45    960706.2254            64628348.63      27
```

Owner
Plant Unit
Project No. File No.
Title

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Date 19
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DO NOT WRITE IN THIS SPACE

```
 57147471.4        28         0.08        11
      1582.        29         182.        12
         1.        30           6.        13
         1.        31         0.02        14
1.000261158        32         0.05        15
 1.00030639        33           4.        16
30.42105263        34          0.1        17
        19.        35           0.        18
        0.9        36        0.059        19
        43.        37          26.        20
     0.7958        38         0.15        21
        59.        39           1.        22
         0.        40           0.        23
        0.2        41           0.        24
        0.3        42           0.        25
        0.4        43           1.        26
        0.5        44  64628348.63        27
        0.6        45   57147471.4        28
        0.7        46   1.00030639        29
        0.8        47           6.        30
        0.9        48  .1536900234        31
         1.        49  .1391286413        32
         0.        50  1.000210874        33
      0.063        51  30.33333333        34
     0.1295        52        1582.        35
     0.1976        53  1612.333333        36
     0.2558        54         1.15        37
     0.3347        55           0.        38
     0.4531        56   943318.635        39
     0.5917        57  79980713.34        40
     0.7958        58  1599614.267        41
         1.        59  12292237.71        42
                       7998071.334        43
                       943772.4175        44
                       8254009.617        45
                       11127607.98        46
                       12796749.18        47
                       11852976.76        48
                       8254009.617        49
                       11852976.76        50
  44768000.        01           0.        51
     0.0575        02           0.        52
        0.1        03           0.        53
      1004.        04           0.        54
         0.        05           0.        55
       578.        06           0.        56
        19.        07           0.        57
         0.        08           0.        58
         1.        09           0.        59
    809000.        10
```

OUTPUT DATA, PROG. 2
PARTIAL STEAM LOOP
6/22/82

BLACK & VEATCH
CONSULTING ENGINEERS

Owner	Computed By
Plant / Unit	Date 6/22 19 82
Project No. / File No.	Checked By
Title	Date 19
	Page 1 of 2

DO NOT WRITE IN THIS SPACE

INPUT DATA, PROG. 1
FULL STEAM LOOP
6/22/82

```
        0.        00
 73339000.        01
    0.0575        02
       0.1        03
     1004.        04
        0.        05
      578.        06
       19.        07
        0.        08
        1.        09
  1050000.        10
      0.08        11
      182.        12
        6.        13
      0.02        14
      0.05        15
        4.        16
       0.1        17
        0.        18
     0.059        19
       26.        20
      0.15        21
        1.        22
        0.        23
        0.        24
        0.        25
        0.        26
        0.        27
        0.        28
        0.        29
        0.        30
        0.        31
        0.        32
        0.        33
        0.        34
        0.        35
        0.        36
        0.        37
        0.        38
        0.        39
        0.        40
       0.2        41
       0.3        42
       0.4        43
       0.5        44
       0.6        45
```

```
       0.7        46
       0.8        47
       0.9        48
        1.        49
        0.        50
     0.063        51
    0.1295        52
    0.1976        53
    0.2558        54
    0.3347        55
    0.4531        56
    0.5917        57
    0.7958        58
        1.        59
```

OUTPUT DATA, PROG. 1
FULL STEAM LOOP
6/22/82

```
 1592942.353
 1605646.538
 1618452.042
 1993884.047
 3471448.303
 3524391.035
 3611901.884
 3429001.506
 3136256.632
 3723450.675
 4319817.375
 5662205.565
 6586275.024
 7431645.985
 7833415.539
 10881059.62
 11720083.75
 11818764.19
 11913605.74


 105874250.8


 1578160.232
 1575996.764
 1573830.279
 1920926.055
  3313402.06
```

```
 3332730.613
 3383800.533
 3182652.138
 2083937.054
 3392132.646
 3898925.578
 5063116.006
 5834784.152
 6522628.346
 6811479.791
 9373767.651
 10002910.32
 9993564.877
 9980315.712


  93619067.3
```

```
   73339000.        01
      0.0575        02
         0.1        03
       1004.        04
          0.        05
        578.        06
         19.        07
          0.        08
          1.        09
    1050000.        10
        0.08        11
        182.        12
          6.        13
        0.02        14
        0.05        15
          4.        16
         0.1        17
          0.        18
       0.059        19
         26.        20
        0.15        21
          1.        22
          0.        23
          0.        24
          0.        25
          1.        26
 105874250.8        27
  93619067.3        28
       1582.        29
          1.        30
```

BLACK & VEATCH
CONSULTING ENGINEERS

Owner
Plant Unit
Project No. File No.
Title

Computed By
Date 6/22 19 82
Checked By
Date 19
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DO NOT WRITE IN THIS SPACE

```
          1.          31
 1.000261158          32
  1.00030639          33
 30.42105263          34
         19.          35
         0.9          36
         49.          37
      0.7958          38
         59.          39
          0.          40
         0.2          41
         0.3          42
         0.4          43
         0.5          44
         0.6          45
         0.7          46
         0.8          47
         0.9          48
          1.          49
          0.          50
       0.063          51
      0.1295          52
      0.1976          53
      0.2558          54
      0.3347          55
      0.4531          56
      0.5917          57
      0.7958          58
          1.          59
```

OUTPUT DATA, PROG. 2
FULL STEAM LOOP
6/22/82

```
   73339000.          01
      0.0575          02
         0.1          03
       1004.          04
          0.          05
        573.          06
         19.          07
          0.          08
          1.          09
    1050000.          10
        0.08          11
        182.          12
          6.          13
        0.02          14

        0.05          15
          4.          16
         0.1          17
          0.          18
       0.059          19
         26.          20
        0.15          21
          1.          22
          0.          23
          0.          24
          0.          25
          1.          26
 105874250.8          27
  93619067.3          28
  1.00030639          29
          6.          30
 .1526900234          31
 .1391286413          32
 1.000210874          33
 30.33333333          34
       1582.          35
 1612.333333          36
        1.15          37
          0.          38
 1224331.974          39
 130582536.8          40
 2611650.737          41
 20069233.14          42
 13058253.68          43
 1540873.535          44
  13476117.8          45
 18167770.93          46
 20892936.57          47
 19352062.64          48
  13476117.8          49
 19352062.64          50
          0.          51
          0.          52
          0.          53
          0.          54
          0.          55
          0.          56
          0.          57
          0.          58
          0.          59
```

APPENDIX J

ESTIMATED O&M COST FOR 1,000 tpd WASTE-TO-ENERGY PLANT

APPENDIX J

ESTIMATED O&M COST FOR 1,000 tpd WASTE-TO-ENERGY PLANT (Third quarter 1981 $)

Cost Element		Annual Cost
Payroll (45 x $30,000)		$1,350,000
Utilities		50,000
Maintenance		
Material/supplies		
Chemicals		
Contract labor		1,100,000
Insurance		200,000
	Subtotal	$2,700,000
G&A expenses (5%)		135,000
	Subtotal	$2,835,000
Contingency fund (20%)		565,000
	Total	$3,400,000
		($12.41/ton)[1]

---

[1] Based on 274,000 tons/yr throughput (see Appendix E, Table E-2).

MAB 22 March 82

2147-01-01

Southwest Brooklyn Incinerator Feasibility Study
Performance/Cost Estimate from S. Brokema, DELTAK

Re-design of waste heat boilers to accomodate recirulation of exit gas to attemparate inlet temperature to 1200F:

Inlet temp: 1200F
Outlet temp: 450F
Gas flow: 54,200 SCFM

Boiler will generate 45,645 pph of steam @ 650psig, 700F, with a feedwater temperature of 280F.

Boiler tubes will be fabricated of carbon steel, as will be superheater and economizer sections. An optional Al coating on the superheater tubes is available for $250,000 for all four superheaters

Approximate boiler tube life is in the area of 10 years. Tube metal temperature is 800F in superhater, 330F in economizer section.

Sandy reported that the budget cost estimates given to B&V by Locke were incorrect. DELTAK's cost estimate for four boilers (to accomidate recirulation) is $1,825,000.

BLACK & VEATCH

CONFERENCE MEMORANDUM

S. W. Brooklyn Incinerators
Deltak Waste Heat Boiler
Information

B&V Project 9453
July 10, 1981

A meeting was held at B&V to obtain the waste heat boiler parameters as requested of Deltak in phone calls of June 30th and July 1st. Tim Locke attended and represented Deltak; Earl Smith and Kermit Trout were also present. Locke discussed Deltak's experience in the waste heat boiler field and provided representative parameters for for S. W. Brooklyn project. The sketches, calculations and price estimates are attached.

dlw

42,800 SCFM ∴ = 199,500 #/hr

650 psig OPERATING
T_s 497°F h_f 484 h_g 1202

280°F FEEDWATER h_f 249

650°F SUPERHEAT h_g 1319

48,000 #/hr STEAM FLOW

DUTY 51×10⁶ BTU/hr

Super heater 5.6×10⁶ BTU/hr
ΔT = 96°F

BOILER 34.3×10⁶ BTU/hr
1304 → 660 = 644 ΔT F.G.

ECONOMIZER 12.3×10⁶ BTU/hr
660 → 440 = 220 ΔT F.G.

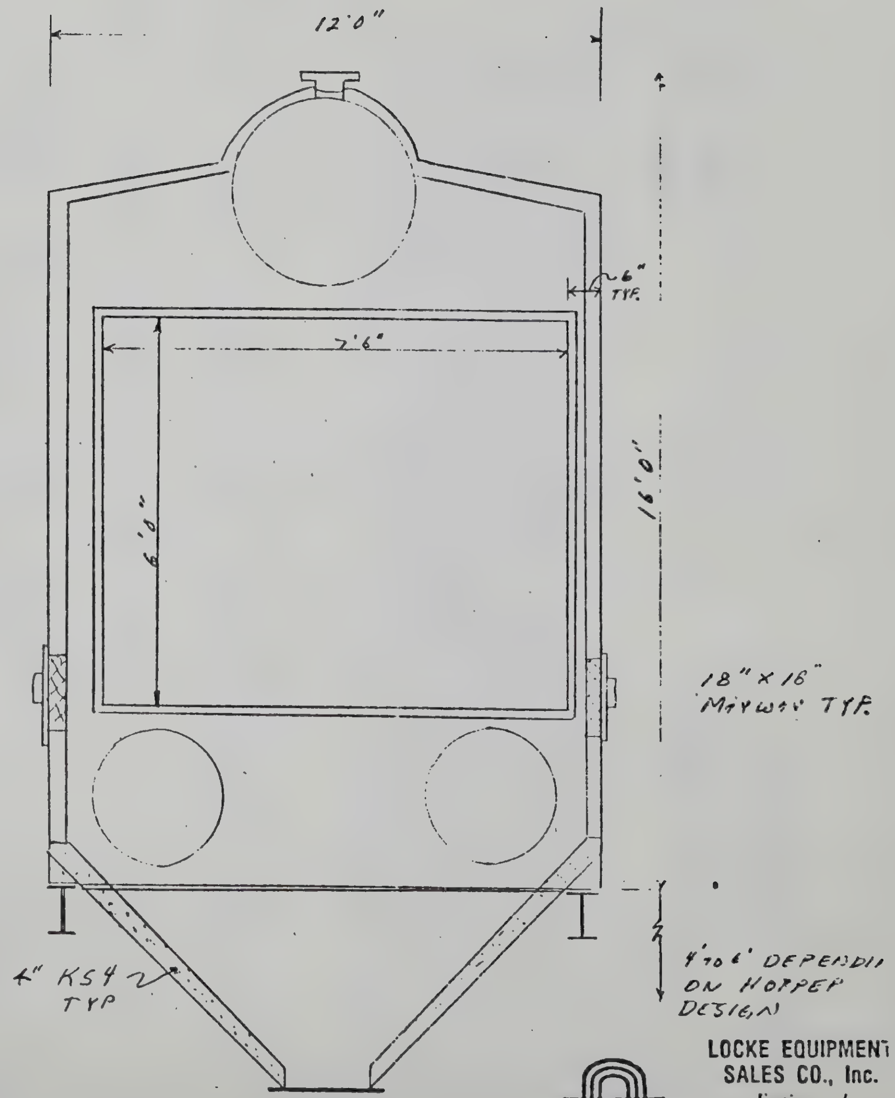
Boiler 30' Long 16' TALL × 12' WIDE
Super heater 5' LONG
Economizer 9' Long

10% OFF ON 4 UNIT IDENTICAL UNITS

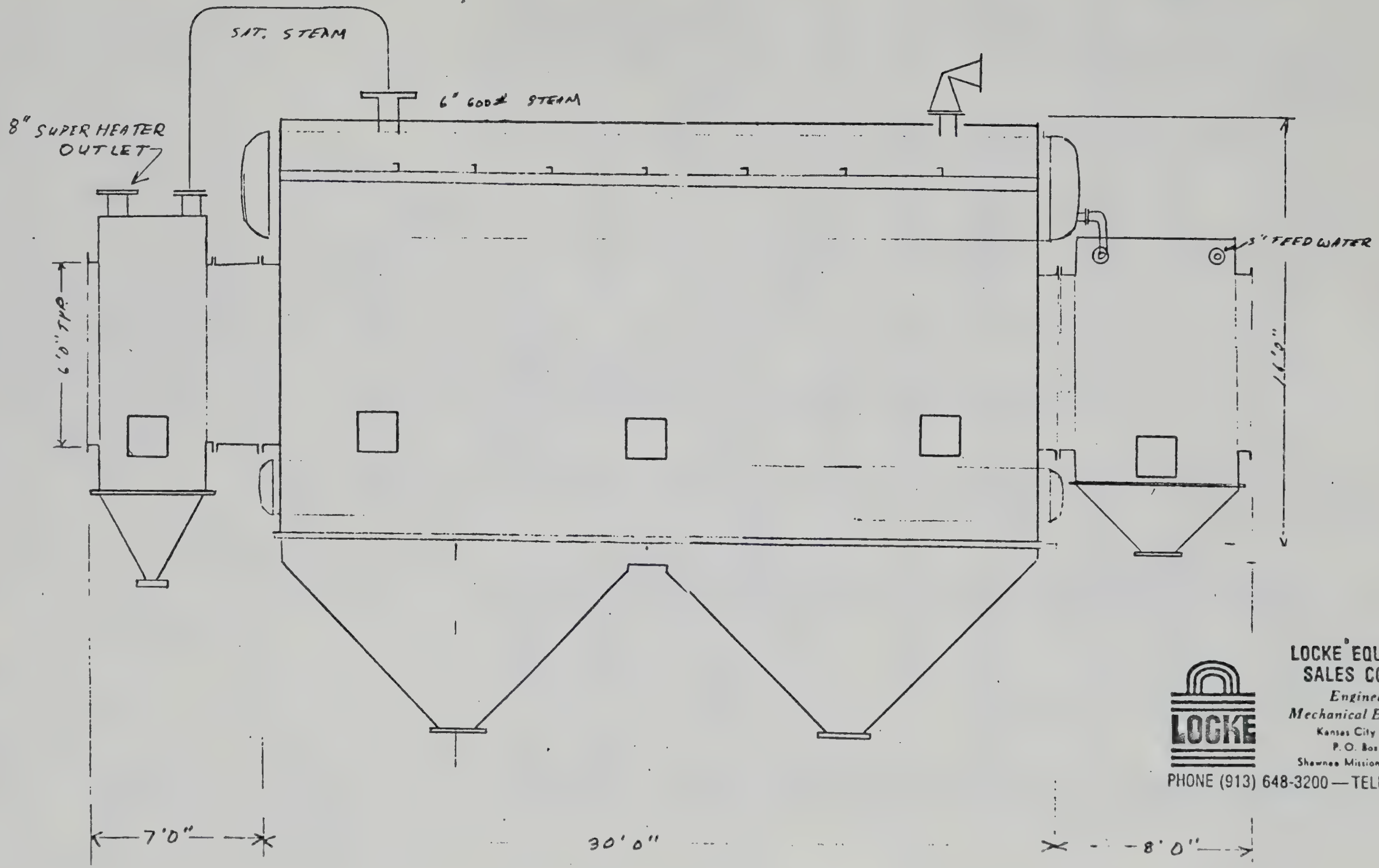
With hoppers, Boiler TRIM
ECONOMIZER

APPROX. WEIGHT 300,000 lbs

APPROXIMATE COST $600,000
Boiler + TRIM
ECONOMIZER + SUPERHEATER
HOPPERS
NO STRUCTURAL.



LOCKE EQUIPMENT
SALES CO., Inc.
Engineered
Mechanical Equipment
Kansas City Office:
P. O. Box 243
Shawnee Mission, KS 66201
PHONE (913) 648-3200 — TELEX 42-6



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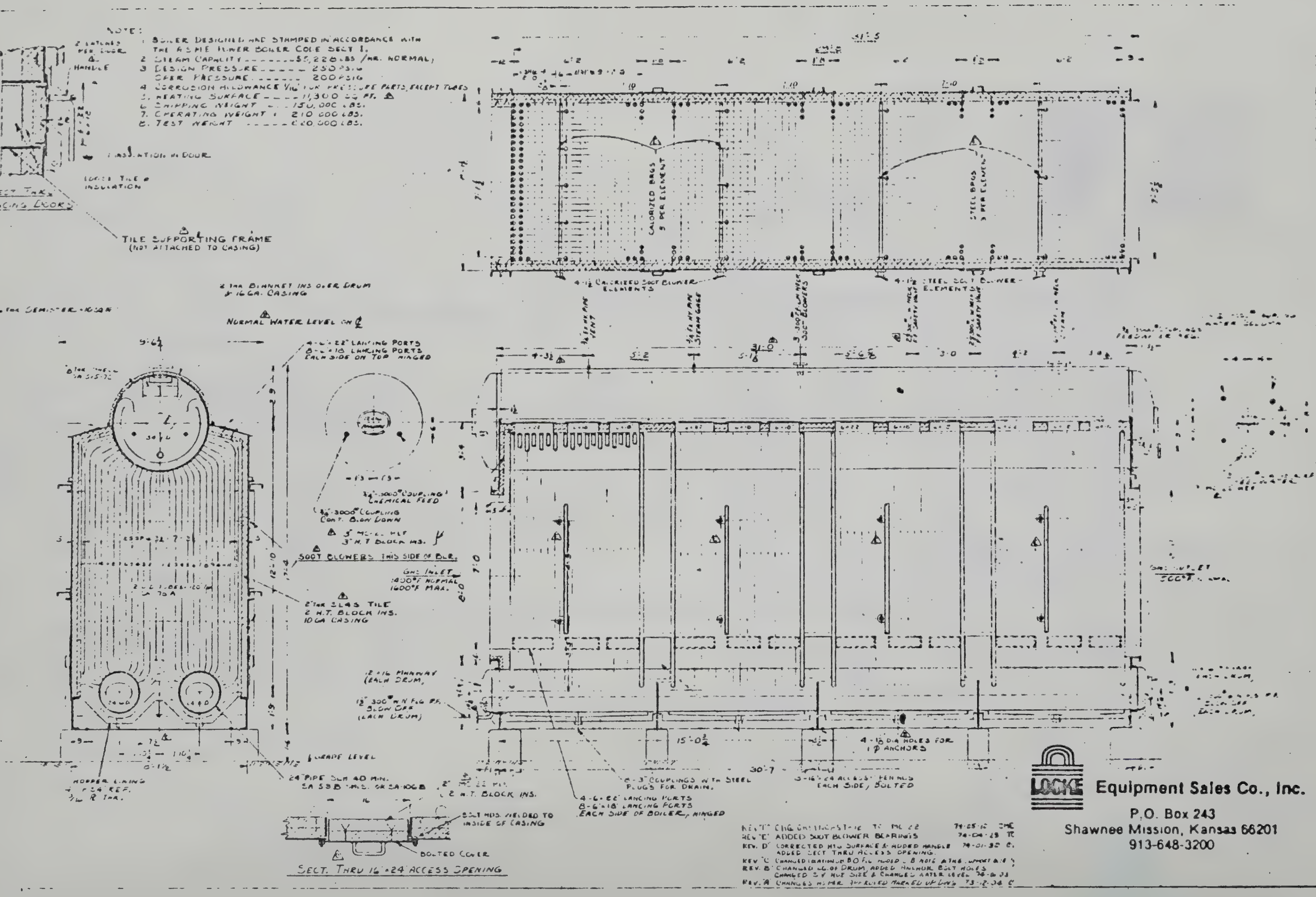


SECT. THRU LANCING DOORS
2 LATCHES PER DOOR
HANDLE
INSULATION IN DOOR
LOCKE TILE & INSULATION
TILE SUPPORTING FRAME (NOT ATTACHED TO CASING)
2 IN. BLANKET INS OVER DRUM & 16 GA. CASING
NORMAL WATER LEVEL ON ℄
4-6×22 LANCING PORTS
8-6×18 LANCING PORTS
EACH SIDE ON TOP HINGED
CHEMICAL FEED
CONT. BLOW DOWN
3" H.T. BLOCK INS.
SOOT BLOWERS THIS SIDE OF BLR.
GAS INLET 1400°F NORMAL 1600°F MAX.
2" SLAS TILE
2 H.T. BLOCK INS.
10 GA CASING
12×16 MANWAY (EACH DRUM)
1½" 300# W.N FLG FF. BLOW OFF (EACH DRUM)
GRADE LEVEL
HOPPER LINING
24" PIPE SCH 40 MIN. SA 53 B SMLS. OR SA-106 B
2 H.T. BLOCK INS.
BOLT HDS. WELDED TO INSIDE OF CASING
BOLTED COVER
SECT. THRU 16"×24" ACCESS OPENING
CALORIZED BAGS 9 PER ELEMENT
STEEL BAGS 9 PER ELEMENT
4-1½ CALORIZED SOOT BLOWER ELEMENTS
4-1½ STEEL SOOT BLOWER ELEMENTS
VENT
STEAM GAGE
SOOT BLOWERS
SAFETY VALVE
GAS OUTLET 500°F
15'-0¾
30'-7
4-1⅝ DIA HOLES FOR 1 ⌀ ANCHORS
3-16"×24 ACCESS OPENINGS EACH SIDE, BOLTED
8-3" COUPLINGS WITH STEEL PLUGS FOR DRAIN.
4-6×22 LANCING PORTS
8-6×18 LANCING PORTS
EACH SIDE OF BOILER, HINGED

NOTE:
1. BOILER DESIGNED AND STAMPED IN ACCORDANCE WITH THE A.S.M.E. POWER BOILER CODE SECT I.
2. STEAM CAPACITY .... 55,220 LBS/HR. NORMAL
3. DESIGN PRESSURE .... 250 PSIG
OPER. PRESSURE .... 200 PSIG
4. CORROSION ALLOWANCE 1/16" FOR PRESSURE PARTS, EXCEPT TUBES
5. HEATING SURFACE .... 11,300 SQ. FT.
6. SHIPPING WEIGHT .... 150,000 LBS.
7. OPERATING WEIGHT .... 210,000 LBS.
8. TEST WEIGHT .... 220,000 LBS.

REV. "F" CHG. [illegible] TO [illegible] 74-05-16
REV. "E" ADDED SOOT BLOWER BEARINGS 74-04-29
REV. "D" CORRECTED HTG. SURFACE & ADDED HANDLE 74-01-30
ADDED SECT THRU ACCESS OPENING.
REV. "C" [illegible]
REV. "B" CHANGED [illegible] OF DRUM, ADDED ANCHOR BOLT HOLES
CHANGED [illegible] SIZE & CHANGED WATER LEVEL 74-01-03
REV. "A" CHANGES AS PER [illegible] MARKED UP DWG 73-12-04

LOCKE Equipment Sales Co., Inc.
P.O. Box 243
Shawnee Mission, Kansas 66201
913-648-3200

BLACK &
VEATCH
CONSULTING
ENGINEERS

TELEPHONE MEMORANDUM

DATE July 1, 1981

(TO) (~~FROM~~) Tim Locke 648-3200

TIME 4:15 ~~AM~~ PM

COMPANY Locke Equipment - Deltak

CC:

RECORDED BY Kermit Trout

PROJECT S. W. Brooklyn NO. 9453

SUBJECT Waste Heat Boiler Parameters FILE NO.

Tim returned my call to verify some design information. Design parameters 42,800 scfm 1400 F in 450 F min out. 4 waste heat boilers to supply one T/G. Tim will price out deaerator also.

I requested structural data per Karl Danz, explained our position and that we would appreciate Locke's help.

A meeting was set up for July 10th. Locke will have all information by then. Sizes, costs, performance, etc.

Also discussed the possibility of a plant trip to Minn. to visit the factory. Told him it might be planned in September or so.

dlw

BLACK &
VEATCH
CONSULTING
ENGINEERS

TELEPHONE MEMORANDUM

DATE June 30, 1981

~~(TO)~~ (FROM) Tim Locke (648-3200)

TIME 3:00 ~~AM~~ PM

COMPANY Locke Equipment Sales (Deltak)

CC:

RECORDED BY M. J. Eddington

PROJECT Weston/PASNY NO. 9453

SUBJECT Waste Heat Recovery Boiler FILE NO.

Based on the following, what is steam flow?

Gas Flow:	Steam Flow:
42,800 scfm	280 F feedwater
1,400 F inlet	700 F outlet
450 F outlet	650 psig

Based on .075 or .076 #/scf and Cp=.27, steam flow would be about 42,000 #/h. I asked Tim for pricing information, i.e., HRSG and any auxiliaries, and what these are (scope of supply) and erection costs. Dimensions for equipment were also requested, as was a schedule of delivery. Tim mentioned that for typical industrial applications, FW inlet would be approximately 220-230 F and drum steam would be used for the Deaerator. This would provide more steaming capacity and a smaller economizer section. He guessed a 50 psi drop thru the boiler.

The boiler should be shop erected as far as possible. It would consist of a steam coil, superheat coil, economizer and drum. The unit would probably be shipped such that the economizer and convective sections would flange together with an interconnecting pipe shipped loose to the field. The steam drum would be placed on these sections. 6-8 field welds would be required.

Tim mentioned that they also sell DA's and feedwater pumps.

Tim was advised that we were a subcontractor to R.F. Weston and they would require a courtesy copy of any correspondence:

Karl Danz, R. F. Weston, Weston Way, Westchester, PA. 19380

dlw

LOCKE
MANUFACTURERS' REPRESENTATIVE: ENGINEERED MECHANICAL EQUIPMENT

LOCKE EQUIPMENT
SALES COMPANY INC
P O BOX 243
SHAWNEE MISSION KANSAS 66201
(913) 648 3200 TELEX 42 6136

January 7, 1981

Black & Veatch
Consulting Engineers
P. O. Box 8405
Kansas City, MO 64114

Attention: Mr. Kermit Trout

Subject: Southwest Brooklin Incinerator Project

Dear Mr. Trout:

The purpose of this letter is to confirm some preliminary information for use in your feasibility study.

For recovering steam from an incinerator process incinerating municipal refuse with a hot gas flow of 56,000 SCFM of gas, and to generate steam at 650°F TT and 650 PSIG, we would recommend a Deltak Dyno Boiler similar to that described in the attached literature.

Based on the information you have given us, we have estimated the hot gas flow to be approximately 261,000 lbs./hr. For the initial gas temperature across the superheater section, we would take a temperature drop of about 1400-1304°.

Across the steam generating section, we would have a temperature drop of 1304-660°. The unit would have an Economizer which should have feedwater flowing to it at 280°F and it would take a temperature drop of 660°F to cooling the gases to 440°F.

Based on this type of a train of heat recovery equipment, we could generate approximately 64,400 lbs./hr. of steam at 650°F TT and 650 PSIG.

The unit would be made completely of bare tubes to avoid excessive fouling. It would be fabricated throughout of carbon steel and a budgetary estimate for its cost, FOB our factory, would be approximately $500,000.

I trust the information we have supplied you is helpful in your study. Obviously we are most anxious to follow this should the project become a viable project.

We would appreciate your letting us know as we would be anxious to work with Black & Veatch in any way we can as we feel that we have an excellent boiler to supply for this process.

Very truly yours,

LOCKE EQUIPMENT SALES CO., INC.

R.W. Locke
Robert W. Locke
Sales Representative for
Deltak Corporation

RWL:lmk

cc: Deltak (Mr. Csathy)

APPENDIX K

THEORETICAL ENERGY AVAILABILITY

APPENDIX K

THEORETICAL ENERGY AVAILABILITY

The heat available from the flue gases can be calculated by the following general equation:

Heat Input - Heat Losses = Heat Available

A sample calculation using this equation is presented in Table K-1 and explained as follows:

1. Heat Input.

   Heat input is dependent on the composition of the refuse. Municipal refuse consists primarily of cellulose and similar materials, mixed with varying amounts of proteins, fats, oils, waxes, rubber, and plastics.(3) Moisture content can vary from 20 to 50 percent, while the noncombustible portion can range from 10 to 25 percent. The heating value of the combustibles taken alone is approximately 8,500 Btu/lb. Using a refuse moisture content of 26 percent, and a noncombustible fraction of approximately 25 percent, the heating value of the refuse (as received) is approximately 4,370 Btu/lb.

   Carbon and hydrogen are the essential fuel elements in municipal refuse. Stoichiometrically, the complete combustion of this fuel (using 26 percent carbon and 3.4 percent hydrogen, by weight) requires 3.53 lbs air/lb refuse. The water vapor associated with the combustion air contains a vapor enthalphy of 1,048 Btu/lb (at 80°F) which represents a portion of the heat input.

2. Heat Losses.

   Heat losses in the incineration process result from vaporization of moisture, losses in fly ash and residue, and heat transfer through the furnace enclosure.

Table K-1

Theoretical Heating Value Calculations
(per 100 lbs of refuse)

Heating Values	Quantity
Heat Inputs at 80°F	
Refuse[1]	437,000 Btu
Water vapor in combustion air (140% excess)[2]	12,000
	449,000
Heat Losses	
Heat of vaporization[3]	97,200
Heat in fly ash[4]	800
Heat in residue[5]	625
Loss through furnace enclosure[6]	13,500
Total Losses	112,125
Balance to heat flue gas	336,875 Btu
Total flue gas[7] (at 140 percent excess air)	951 lb
Enthalphy of flue gas	354 Btu/lb
Total moisture	11%
Flue gas temperature	1,325°F
Flue gas volume (at 250 tpd)	43,200 SCFM
Energy Available from Waste Heat Boilers[8]	190,600,000 Btu/hr

---

[1] Heating value at 4,700 Btu/lb.

[2] Assumes vapor enthalphy at 1,048 Btu/lb; stoichiometric air requirement at 3.53 lbs/lb refuse; 0.0135 lbs moisture/lb air.

[3] Includes refuse moisture at 26 percent, bound water at 61.8 percent, and residue quenching vapor at 5 percent; total moisture = 92.8 lbs/100 lbs refuse.

[4] Assumes 2 lbs fly ash/100 lbs refuse; specific heat = 0.25 Btu/lb °F; temperature at 1,680°F.

[5] Assumes 0.25 lb residue/lb refuse; specific heat = 0.25 Btu/lb °F; temperature at 180°F.

[6] Three percent of total heat input.

[7] Includes 104.2 lbs water vapor.

[8] Assumes inlet temperature = 1,325°F, outlet temperature = 450°F, specific heat = 0.275 Btu/lb - °F.

The combustion of cellulose (carbon and hydrogen) results in the production of moisture due to the release of "bound" water. For the fuel composition just described, complete combustion of 100 lbs of refuse will produce 61.8 lbs of water. It is estimated that an additional 5 lbs will be released by quenching the residue. This moisture will be vaporized in the furnace, resulting in an energy loss equal to the heat of vaporization of the bound water, quench water vapor, and the original moisture content of the refuse.

Additional heat losses are the result of particulate emissions (fly ash) and ash removal. For this calculation, exit temperatures for fly ash and residue were estimated as 1,680°F and 180°F, respectively.

Heat loss through the furnace enclosure is a function of furnace construction, and was estimated to be 3 percent of the total heat input.

3. Heat Available.

The difference between the total heat input and total losses (336,875 Btu) is the energy available to heat the flue gases. Operating the furnaces at 140 percent excess air requires 8.47 lbs air/lb refuse; on a 100-lb basis, 847 lbs of air is required. Accounting for the 92.8 lbs of moisture vaporized, the total weight of the flue gas is 951 lbs. Therefore, the resulting heat transferred to the flue gas is 354 Btu/lb. Total moisture in the flue gas is 104.2/951, or 11 percent. The enthalphy and moisture content correspond to a gas temperature of 1,325°F. Extrapolating the flue gas production rate of 9.51 lbs gas/lb refuse to a furnace throughput of 250 tpd results in a flue gas flow of 43,200 SCFM per furnace. Assuming an inlet temperature of 1,325°F to the waste heat boilers and an inlet temperature of 450°F, the total energy available from four furnaces is approximately 190,600,000 Btu/hr.

APPENDIX L

TRIP REPORTS

Memo To: A. Thau

From: W. Chesner

Date: 10 November 1981

cc: B. Shrivastava
M. Barbara
K. Danz
E. Smith
H. Szarpanski

I. TRIP REPORT - PITTSFIELD, MASS. RESOURCE RECOVERY PLANT; 26 OCTOBER 1981

(1) Trip Participants

A. Thau - PASNY
B. Shrivastava - NYC DOS
W. Chesner - Weston
M. Barbara - Weston
E. Smith - B&V

Pittsfield Guides

Lew Clark - Facility Mgr.
Beth Voll - Tour Guide

(2) Facility Background Data

A. Vicon Construction Company, Butler, NJ designed, built and operates the facility; Vicon has another project in Washington County, NY.

B. Facility start-up was end of March 1981.

C. Pittsfield facility is designed to process 240 TPD of refuse (120 TPD per furnace); two furnaces are on-line with one standby.

D. The heat exchangers are convective boilers; two boilers designed for 35,000 pounds/hour are on-line with a third standby.

E. The equipment manufacturers are as follows:

Furnaces: Enercon, Cleveland, Ohio
WHB: Bigelow
Electro Scrubbers: Combustion Power, California

F. The scrubber is a circulating pebble electrostatic precipitator (circulating charged pebbles act as collectors and filters); ash is trucked to the municipal landfill for disposal.

G. Energy (steam) is sent to Crane and Company - Valve Mfg. on a demand basis. The price of steam is keyed to a 15% discount on Fuel Oil No. 6 (700,000 pounds/day minimum). Currently 20,000 pounds/hour is taken by Crane and the excess is vented. Three of five plants are connected with approximately 200 feet of steam pipe; the remaining two are 1-2 miles away and will be hooked up; no condensate return; water makeup costs represent approximately 2% of the steam production costs.

H. A 6.2 million dollar bond was issued by the City to finance the project; Vicon and the City are partners and share the profits 50/50 after all operating costs and debts are paid.

I. Tipping fees at the facility are $13.68/ton for the City of Pittsfield; $12.00/ton for the Town of Lennox. The City of Pittsfield subsidizes its internal haulers who only pay $2.00 per ton (i.e. the City subsidizes $11.68 per ton); City guarantees facility 44,000 tpy.

(3) Facility Operation

A. The entire operation is enclosed in a metal building on one level. The 500 ton pit has several 14' doors for dumping direct to pit. The incinerator loading stations for the incinerator are charged by frontend loaders. The crane operator is located in the control room with the incinerator operator. The frontend loader operator is the only other operator. Women operate the scales from the office at the front gate. Sorting is done on the floor except for hauler sorting which is required for metals.

B. The furnace has five slide along rams to move the garbage through the furnace. Garbage 2-3 feet high is piled on the loading hopper and charged with the rams at constant speed. Recycle of flue gas (2'0 recycle header versus 6'0 flue gas duct) can be used to control the air temperature to the WHB. The recycled flue gas is controlled by an exhaust bypass damper. The gas is introduced into the front face (charging area) of the furnace.

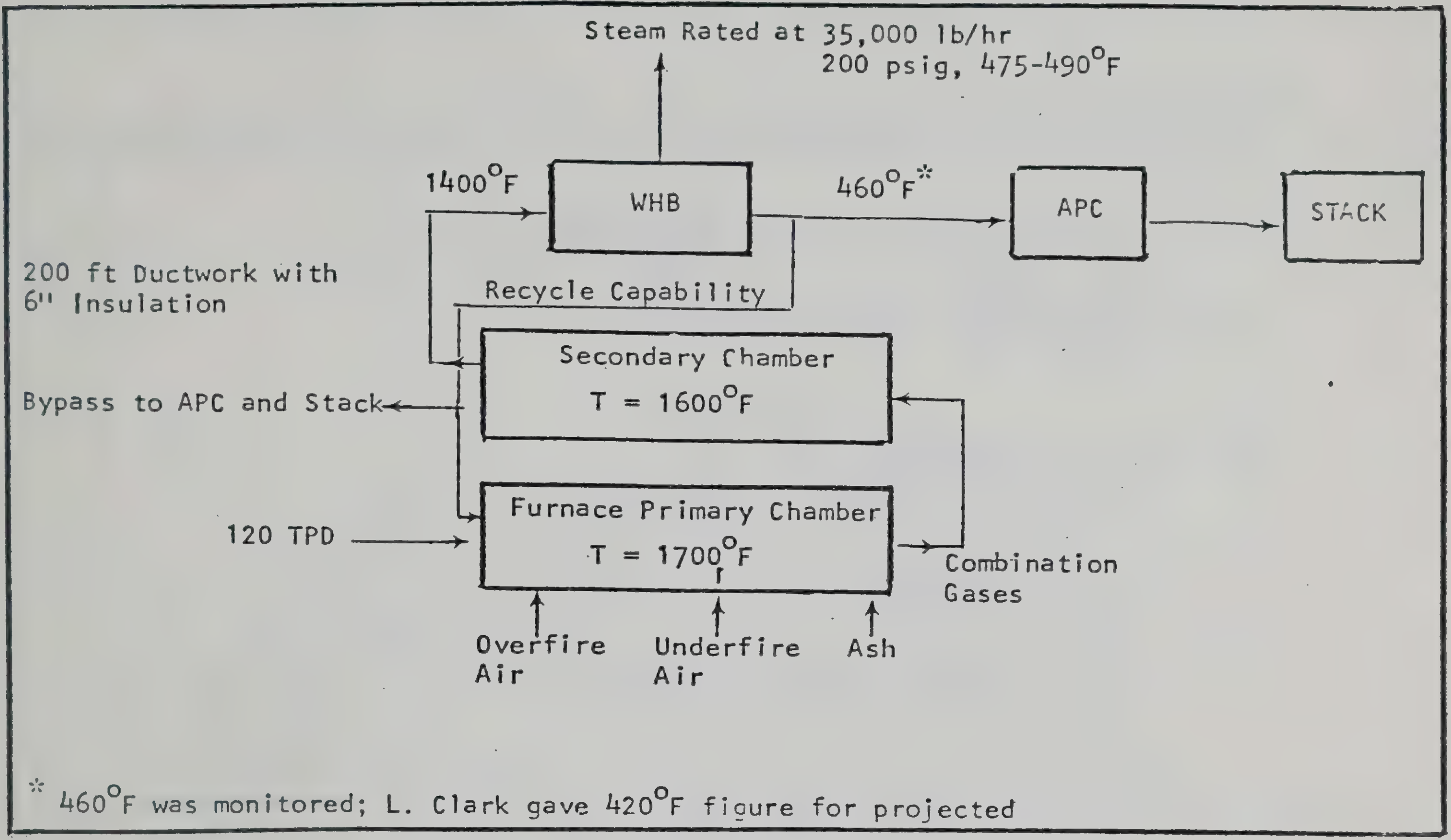
C. Facility has continuously operated since start-up (24 hours - 7 days per week) with 3 day shut down in August for maintenance/ cleaning. Steam soot blowers are used to clean the boilers.

D. Payloader operator sorts and removes large refuse (metal) prior to charging.

E. Approximate solid waste composition - 30% industrial
- 70% municipal

F. Combustion air calculated @ 150% excess air = 20,890 scfm; at a stoichemetric air flow $\frac{432 \text{ lb air}}{100 \text{ lb refuse}} = \frac{4.32 \text{ lbs air}}{\text{lb refuse}}$

G. The process flow scheme and temperature profile of the facility is as follows:



* 460°F was monitored; L. Clark gave 420°F figure for projected

H. The combustion air is first used to cool the combustion chamber refractory. In this way it is preheated to approximately 300°F.

I. The temperature in the combustion chamber is controlled by recirculating a flue gas slipstream.

J. The underfire/overfire ratio can be varied between 3/1 and 1/3.

K. The flue gas ducts contain 6" of brick insulation.

L. The boilers are cleaned once every 4 weeks. This operation is performed, on the average, during one shift. Some slagging of the front tubes of the convection passes were observed particularly during temperature excursions. This has been minimized by maintaining the inlet temperature to the WHB as close to 1400°F as possible.

M. Flue gas dust loading information was not available. The particulate permit limits the stack discharge to 0.05 grains/scf.

II. TRIP REPORT TO PHELPS DODGE, 42-02 56th RD., MASPETH, NY: 27 OCTOBER 1981

(1) Trip Participants

Trip Participants	Phelps Dodge
A. Thau - PASNY	Sam Principe
W. Chesner - Weston	
B. Schrivastava - NYC	
E. Smith - B&V	

(2) Facility Background Data

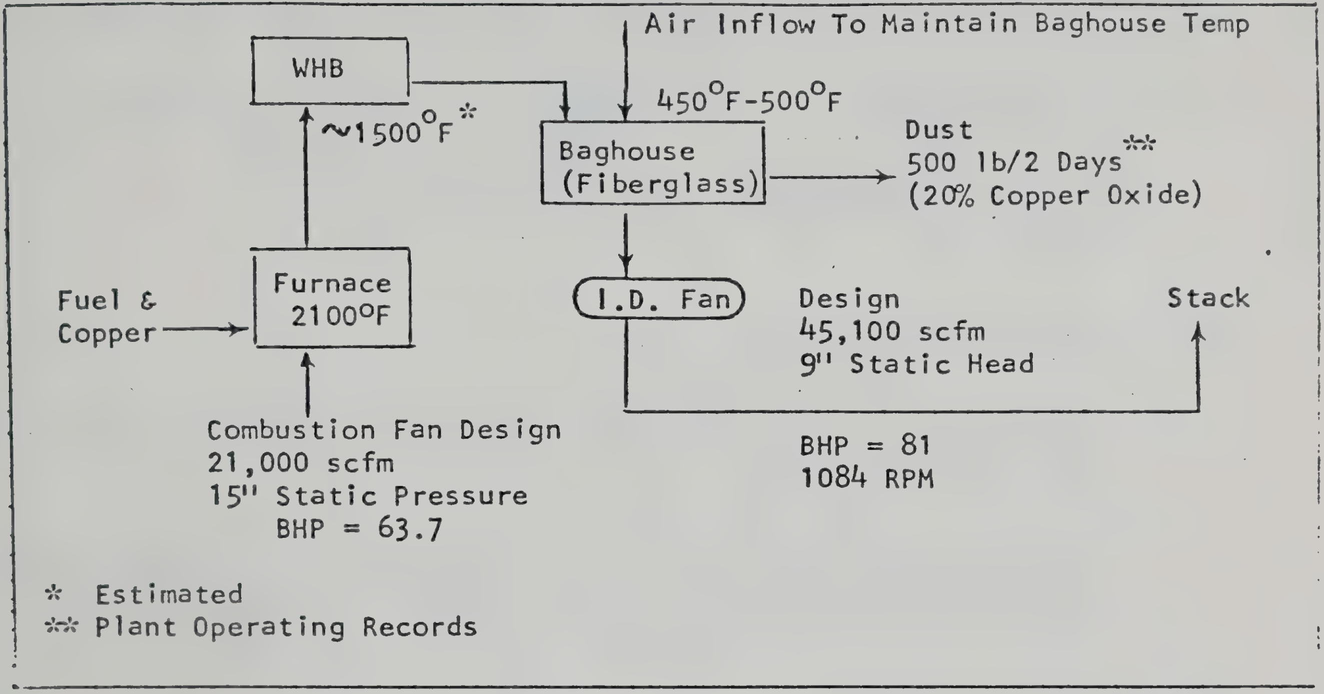
A. Facility is a copper salvage refiner, in which scrap copper is melted in a reverberatory furnace, cast and plated.

B. Facility contains two Babcock & Wilcox boilers and one Erie City boiler (now Zurn-Erie City), fired by oil or natural gas. The Erie City boiler was installed in 1966 and rebuilt in 1974 (i.e. waterwall furnace with convection passes; 12-15" firebrick walls; and retractable soot blowers).

C. An electric wire scrap (including insulation) melting furnace was operated for a four-year period, from 1969-1973. The flue gases from this furnace were cooled in a B&W convection boiler. Major corrosion problems occurred throughout the flue gas train during this period due to highly corrosive HCl gases released from PVC insulation. The boiler was washed with soda ash an kept as dry as possible during downtime. Sam Principe (Plant Manager) estimates that with an operating schedule of 7 days/week the boiler tubes would have sustained approximately 7 years of service. He indicated that operating data for WHB in dust-loaded corrosive gases can be obtained from copper ore refineries.

(3) Facility Operation

A. The following represents the flow of the present Erie City Boiler:



* Estimated
** Plant Operating Records

B. Slag buildup problems on uptake flue from furnace as gas cools, requiring cleanout.

C. Present steam production = 50,000 lb/hour. Previous B&W convection boiler steam product 25,000 lb/hour, 160 psi 100°F superheat.

III. TRIP REPORT TO CHEVRON REFINERY, PERTH AMBOY, NJ; 27 October 1981

The report is divided into three parts: (1) Participants; (2) Facility Background Data; and (3) Facility Operation.

(1)

Trip Participants	Chevron	Heat Research Corp.
A. Thau - PASNY	C. Lyon	R. Baldwin
W. Chesner - Weston	E. Tout	
B. Schrivastava - NYC		
E. Smith - B&V		

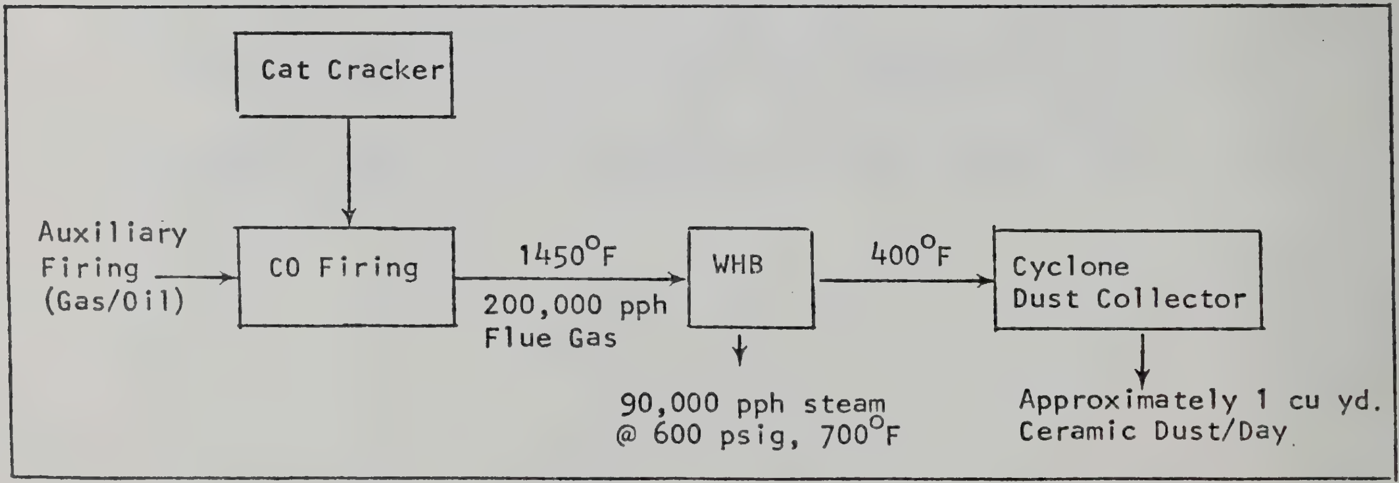
(2) Facility Background Data

A. The facility visited was a Chevron refinery; the unit of interest was a Cat Cracker (regeneration of catalyst by combustion of hydrocarbons in a free fall kiln).

B. Flue gas from this kiln contains CO gas as well as heated flue gas which is combusted along with refinery gas in a Heat Research boiler. A parallel B&W boiler was also installed. The flue gas in both boilers contains approximately 0.6 #/min of clay dust.

(3) Facility Operation

A. The following presents the subject flow train:


Cat Cracker
Auxiliary Firing (Gas/Oil)
CO Firing
1450°F
200,000 pph Flue Gas
WHB
90,000 pph steam @ 600 psig, 700°F
400°F
Cyclone Dust Collector
Approximately 1 cu yd. Ceramic Dust/Day

B. Boiler operation continuous and is shut down every 2-3 years; simultaneously with cat cracker.

C. Combustion air is preheated to 300°F by cooling the refractory. Slag buildup is minimized by rotary steam soot blowers.

APPENDIX M

STOICHIOMETRIC AIR CALCULATIONS

APPENDIX M

STOICHIOMETRIC AIR CALCULATIONS

Refuse Composition (% Composition, as-received)[1]

H_2O	26.00	
S	0.20	
Cl	0.66	
C	24.94	75.03 percent
H_2	3.40	
O_2	19.42	
N_2	0.41	
Inerts	24.97	
	100.00	

HHV = 4,370 Btu/lb

Oxygen Demand

For CO_2 $0.2494 \left(\frac{32}{12}\right) = 0.6651$

For H_2O $\left(0.0340 - \frac{0.0066}{35.46}\right) \frac{32}{4} = \underline{0.2705}$

$\Sigma' = 0.9356$

Less O_2 in refuse $- \underline{0.1942}$

$\Sigma = 0.7414$

Stoichiometric Air

N_2 $\frac{0.7414}{0.21} - 0.7414 = 2.7891$

O_2 $\underline{0.7414}$

Stoichiometric air (lb/lb refuse) = 3.5305

Atmosphere H_2O $\frac{0.7414}{0.21}$ 0.0135 =

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[1] Pope, Evans and Robbins, Spring Creek Refuse Study, December 1979.

APPENDIX N

FURNACE STARTUP AND OPERATIONAL PROCEDURES

APPENDIX N

FURNACE STARTUP AND OPERATIONAL PROCEDURES

The operation of the furnaces is the responsibility of the plant's Senior Stationary Engineer. In order to place one of the furnaces into service, a signal is sent to the charging floor personnel who direct the crane operator to begin filling the appropriate charging chute. Signal lights over each chute indicate which furnaces are in operation. It is the responsibility of the crane operator to maintain a "plug" of refuse in the chute to minimize the infiltration of air into the furnace.

Once the chute has been filled, the reciprocating grates and forced-air fans are activated and the refuse is charged into the furnace. Combustion of the refuse is initiated manually using a torch. The furnace operator, or stationary fireman, manually adjusts the overfire and underfire air flows and sectional grate speeds. Air flows are adjusted using the readings obtained from the furnace draft gauges and temperature indicators on the fireman's control panel. This panel is located adjacent to the furnace. Grate speeds are adjusted based on the required throughput rate. Each of the four grate sections is controlled by a graduated knob on the grate speed control panel. Each knob is graduated in increments of 0 to 10. The speed of the upper, or charging grate, controls the throughput rate of the furnace. The operators use a rule-of-thumb that the knob setting is half the throughput rate in tons/hr (i.e., a setting of 4 1/2 corresponds to 9 tons/hr, or 216 tpd). This approximation was verified by WESTON personnel using actual bucket counts during furnace operation (see Appendix B, p. B-7). The speeds of the three subsequent grates are set to spread out the refuse bed while maintaining the position of the fire on the three uppermost grate sections.

Typically, the charging grate is set on a speed of 4 1/2 to 5 1/2, corresponding to a refuse throughput rate of approximately 216 to 265 tpd. Overfire and underfire air dampers are set to 1/2 and 3/4 open, respectively. As the furnace approaches equilibrium, damper settings are manually adjusted to maintain a combustion chamber temperature of approximately 1,600°F without excessive fly ash entrainment in the flue gas stream.

Siftings and ash residue are collected in water-filled quench troughs located directly below the furnaces and are transported to the residue barge by a series of drag-flight conveyors.

Flue gases are drawn through the secondary chamber and breeching, and exit from one of two masonry stacks.

APPENDIX O

CORRESPONDENCE

BLACK &
VEATCH
CONSULTING
ENGINEERS

TELEPHONE MEMORANDUM

DATE June 8, 1982

(TO) (~~FROM~~) Mr. Jerry Kelpin (212) 566-4107

TIME 3:15 ~~AM~~ PM

COMPANY New York City Dept. of Environmental Protection

CC: EOS

RBH

KET

RECORDED BY D. M. Lefebvre DML

PROJECT Southwest Brooklyn Incinerator NO. 9453

SUBJECT City Permit Process FILE NO.

Both the city and state have a environmental review process. If both entities require an environmental review, a lead agency will be designated. Ms. Kelpin estimated that the environmental review process would take 4 to 6 months to complete after submission of the Environmental Report. The procedural steps of this process are listed below.

20 days to determine whether the ER is complete or to evaluate supplemental information.

15 days to publish public notice.

60 days for a public comment period and, if necessary, hearings.

30-90 days to issue a final decision.

No city or state permit can be issued until the environmental review process is completed. Ms. Kelpin indicated that the city operation permit and pretreatment approval are usually ready to be issued by the time the environmental review process is completed.

cmm

BLACK &
VEATCH
CONSULTING
ENGINEERS

TELEPHONE MEMORANDUM

DATE June 10, 1982

(TO) ~~(FROM)~~ Dick Fram (212) 488-2760

TIME 10:35 AM ~~PM~~

COMPANY New York Department of Environmental Conservation

CC: E.O.S.

RECORDED BY D. M. Lefebvre

R.B.H.

PROJECT Southwest Brooklyn Incinerator NO. 9453

K.E.T.

SUBJECT PSD Permit

FILE NO.

Mr. Fram works for Mr. Cava and is familiar with the Southwest Brooklyn Incinerator. Mr. Fram stated that he understands that the City intends to go to seven day a week, 24 hours a day operation once the operation of the precipitators is normalized. Since the cogeneration modifications will not increase emissions over those which will occur upon continuous operation of the incinerator, Mr. Fram indicated that no PSD permit or other air pollution control permit will be required.

vb

BLACK &
VEATCH
CONSULTING
ENGINEERS

TELEPHONE MEMORANDUM

DATE May 25, 1982

(TO) (~~FROM~~) Gordon Colvin

TIME 9:00 AM PM

COMPANY Department of Environmental Conservation

CC: KET

RECORDED BY R. B. Hosford RBH

PROJECT S.W. Brooklyn Feasibility NO. 9453

SUBJECT Environmental Impact Requirements FILE NO.

I called Gordon Colvin to discuss the potential requirements for an EIS for the addition or modification to the Southwest Brooklyn Incinerator. During our discussions Mr. Colvin indicated that the following points would have to be considered.

1. He thought that the incinerator is presently under a consent order for air pollution abatement. Any additions or plans to modify emissions would need to be consistent with this order. He also believed that either a modification to the existing permit or a new permit would be required.

2. It was his opinion that the involvement of the City of New York and PASNY would trigger the state environmental review process. The question of which agency would act as lead agency would have to be determined. It is possible it could be the City, PASNY or even the Department of Environmental Conservation.

3. The state of New York has been fully delegated the authority to administer the NPDES program, and the Department of Environmental Conservation would be agency to deal with.

BLACK &
VEATCH
CONSULTING
ENGINEERS

TELEPHONE MEMORANDUM

DATE March 25, 1982

(TO) (XXXX) Dick Seelinger (312) 391-2000 Ext. 2087

TIME 2:30 XXX PM

COMPANY UOP, Incorporated

CC: KET

EOS

RECORDED BY M. J. Eddington

PROJECT S. W. Brooklyn NO. 9453

SUBJECT Air Preheating Requirements FILE NO.

1. UOP, Incorporated is the correct title. The Solid Waste System Division handles the MSW work.

2. Dick Seelinger stated that the four to five per cent increase in steam flow is based on taking credit for the Btu input into the boiler with air preheating. The four to five per cent is used regardless of the heating value of the fuel. Therefore, the increase is taken whenever air preheating is used. The basis for the increase originates in the ASME Test Code and the definition of how input and output of the furnace is calculated. Air preheating is accounted for as a credit and increases the output. Air preheating increases the heat input regardless of the heating value of the refuse.

3. The NW Chicago plant did not have a UOP designed air preheater since the plant was designed for 4500 Btu per pound refuse. Seelinger said that UOP, Inc. would include an air preheater in the design if it were done today.

4. Theoretically, air preheating is not required whenever the heating value is greater than 5000 Btu per pound. Air preheat coils would be removed from service whenever the heating value of the refuse increased to that value. Below 4500 Btu per pound, air preheating coils would be placed in service.

dlw

BLACK &
VEATCH
CONSULTING
ENGINEERS

TELEPHONE MEMORANDUM

DATE June 8, 1982

(TO) (~~FROM~~) Gordon Colvin (212) 488-2758

TIME 7:45 AM PM

COMPANY NY Dept. of Environmental Conservation

CC: EOS

RECORDED BY D. M. Lefebvre DML

RBH

PROJECT Southwest Brooklyn Incinerator NO. 9453

KET

SUBJECT PSD Permit Process FILE NO.

Mr. Colvin said that delegation of PSD authority to New York is imminent, but has been imminent for some time now. He did not know what was delaying delegation. Since EPA-Region II will retain jurisdiction over PSD permit applications on which it has started its review after delegation, Mr. Colvin indicated we may have to work with both EPA and DEC to complete a PSD permit application for the project. Mr. Colvin recommended that I contact Mr. Tony Cava of DEC who is more familiar with the PSD situation. His phone number is (212) 488-2760.

cmm

MORSE BOULGER, INC.

53-09 97TH PLACE, CORONA, NEW YORK 11368

P. O. BOX 191 – FLUSHING, N.Y. 11352
TELEPHONE: 212-699-5000

November 6, 1981

Roy F. Weston
1044 Northern Boulevard
Roslyn, New York 11576

Attention: Mr. Michael A. Barbara, P.E.
Project Engineer

Reference: Southwest Brooklyn Incinerator

Dear Mr. Barbara:

This letter will confirm our verbal opinions stated regarding pre-heating underfire air to our stokers.

We have the following comments:

1) Since the steel casing below the stoker line is not insulated the skin temperature will be higher than may be considered a "safe" level. Insulation should be installed on the outside surface only. The inside surface must be left "as is" to allow siftings to slide into the conveyor.

2) While we have no concerns about the 250° F pre-heated air, we do not have any long term operating data on its effect upon the grates. This temperature is well below the design temperature of components such as bearings, etc.

I trust this satisfies your needs. If any additional data is needed, please do not hesitate to contact me.

Very truly yours,

MORSE BOULGER, INC.

Robert L. LaBua
Robert L. LaBua
Vice President

RECEIVED
NOV 9 1981
R. F. WESTON
ROSLYN, N.Y.

RLL/je

The City of New York

Department of Sanitation

Norman Steisel Commissioner

Resource Recovery
And Waste Disposal Planning

Paul D. Casowitz Deputy Commissioner
51 CHAMBERS STREET RM. 815 N.Y., N.Y. 10007
TELEPHONE 566-6260

May 27, 1981

Power Authority State of New York
10 Columbus Circle (17th Floor)
New York, New York 10019

Attn: Mr. Albert Thau

RE: Southwest Incinerator
Down Time

Dear Albert,

The contemplated schedule of maintenance of Southwest Incinerator at the time that Waste Recovery becomes operative is as follows:

1. All four (4) furnaces are to be operated concurrently.
   a) Per Furnace - Down for Maintenance every 4th Monday
      - Down for Major Maintenance 45 days per year

Total Downtime per furnace - 90 days/per year.

Very truly yours,

Sy Rubinstein

SY. RUBINSTEIN, P.E.
Deputy Director of Engineering
Project Manager

SCR:jrh
cc: D. Warnett
    S. Rubinstein
    H. Szarpanski

SAVE WATER

NBS-114A (REV. 2-80)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET *(See instructions)*	1. PUBLICATION OR REPORT NO. NBS-GCR-82-409	2. Performing Organ. Report No.	3. Publication Date September 1982

4. TITLE AND SUBTITLE

Feasibility Study for Resource Recovery: Southwest Brooklyn Incinerator

5. AUTHOR(S) Prepared by Weston--Black & Veatch for the New York City Department of Sanitation

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)*

The City of New York
Department of Sanitation
51 Chambers Street
New York, NY 10007

7. Contract/Grant No.

NB81NADA2043

8. Type of Report & Period Covered

GCR--Final Report

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*

Office of Recycled Materials
National Bureau of Standards
U.S. Department of Commerce
Washington, DC 20234

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

The primary purpose of this investigation was to examine both the technical and economic feasibility of exploiting the heating value of the refuse and the material value of the incinerator ash processed at the Southwest Brooklyn Incinerator. Based on the results of field testing, the combustion of municipal refuse at Southwest Brooklyn would be capable of generating 2.2 trillion Btu of energy annually. On the basis of the examination of both the technical requirements and the economics of recovering energy and materials from processed refuse presented in this report, the following conclusions were drawn: (1) the recovery of energy for electricity generation and/or electricity generation with steam production for district heating during the winter months is both technically and economically feasible, and appropriate action should be taken as soon as soon as practical to plan for the preparation of construction contract documents for such an undertaking; and (2) there exists an opportunity in the City of New York for the recovery of incinerator ash for use as asphalt aggregate in City-owned asphalt production facilities in Brooklyn. Further testing is required to verify the full potential of ash utilization. A detailed review of potential corrosion problems, and mitigating measures, as well as the expected waste heat boiler operational life, was undertaken to determine process modifications and equipment requirements to minimize the impact of corrosion on heat recovery operation. A market survey of potential energy users within a three-quarter mile radius of the incinerator was implemented to determine the available steam market.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

destruct heating; electricity production; energy recovery; incineration; New York City; resource recovery; solid waste management; steam production

13. AVAILABILITY

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